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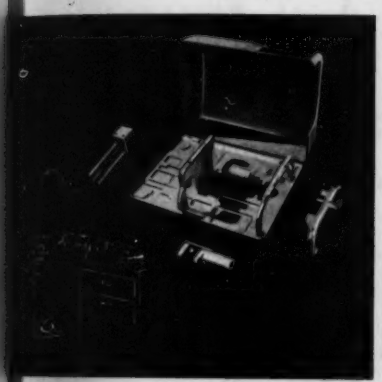

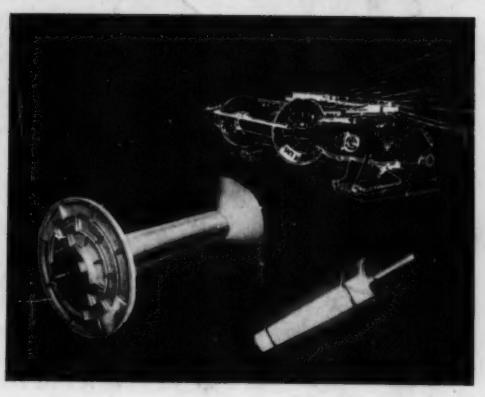

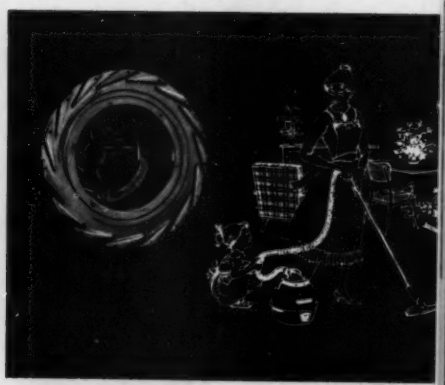

Designing with Magnesium Alloys

page 186

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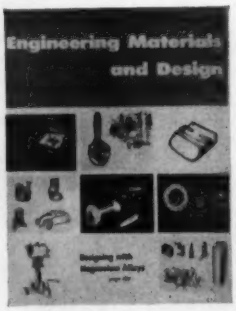

COVER—Some of the current uses of magnesium alloys: Dictaphones, Sankey portable saws, Royal typewriters, Volkswagen cars, textile machinery, Morphy-Richards cleaners, T.V. cameras and printing cylinders.

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ISSUE AT A GLANCE

page

DESIGNING WITH MAGNESIUM ALLOYS **186**
Properties and application of magnesium-based alloy.
By **K. G. Bailey.**

NOISE—ITS NATURE, BEHAVIOUR AND REDUCTION **194**
First of two articles on its characteristics and elimination.
By **D. M. A. Mercer,** M.A., B.Sc.

PROGRESS IN BATTERY CONSTRUCTION **202**
Report of a recent British symposium.
By **D. H. Collins,** B.Sc.

ASBESTOS IN THE SERVICE OF MODERN RAILWAYS **206**
Developments and recent applications of the material.
By **C. Z. Carroll-Porczynski.**

BONDING METALS WITH THERMOSETTING ADHESIVES **211**
Pretreatment and testing for their successful use.
By **E. J. Catchpole,** B.Sc. (Eng.), A.F.R.Ae.S., M.I.A.S.

OTHER FEATURES

New Ideas in Design **199**
Aluminium in Reactor Engineering **205**
Development of Synthetic Quartz **210**
Designer's Notebook **216**
Zirconium: Data Sheet **221**
Torsional Shear Stresses: Data Sheet **223**
Engineering, Marine, Welding and Nuclear Energy Exhibition: Preview **231**

REGULAR FEATURES

Materials in the News ... **179**
Designer's Diary **210**
American Letter **219**
New Books **220**
New Materials and Components **225**
News of Industry **235**

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MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Twin-shell Laminated Plastics

LAMINATES USING POLYESTER, one of the most popular of present-day resins, are relatively economical, possessing good strength in relation to their weight. Where a combination of mechanical strength and resistance to chemical attack is required the polyester laminates may not always be entirely reliable because during the gelation period the resin tends to shrink, thus straining its bond between the glass fibres. Under mechanical strain the fibres are able to move independently and corrosive liquids, helped by capillary action, are able to penetrate into the laminates and attack both resin and reinforcement over a large area.

To overcome this possibility, A. E. Griffiths (Smethwick) Ltd. have introduced a system that employs two distinct layers of reinforced resin, the layer in contact with the corrosive fluid being compounded from furane, which has exceptional resistance to attack by acids and alkalis. As the furane has relatively poor mechanical properties, layers of reinforced polyester are applied to the external surface to produce a twin-shell structure from which it is impossible for the furane laminate to chip or peel as might be the case if it were applied merely as a coating. By using a heat-resistant grade of polyester, the furane/polyester laminate is suitable for temperatures of about 100 deg. C. For more exacting conditions, the polyester may be replaced by an epoxy, and alternative reinforcements such as Terylene or Dynal may be used in place of the conventional glass fibres.

Sisal in Reinforced Plastics

AS LONG AGO as the early 1930s British patents were taken out covering the use of sisal as a plastics reinforcement. It was realised that the contour of the sisal fibre made it most suitable for this purpose, for the re-entrant portion tends to hold the resin securely and to prevent fibres from slipping out of their position in the matrix. The increased adhesion of the plastics mix is thus enhanced with a strengthening of the reinforcing action.

Although originally used only for phenolic moulding powders, recent experience in the U.S.A. has shown its advantages with other resins, such as polyester. Compared with glass fibre, the advantages claimed for sisal are lower cost, lower specific gravity, higher impact strength and longer shelf life in polyester premix compounds. Against these the sisal has lower tensile strength, higher water absorption and lower flexural strength and modulus.

Compared with asbestos-filled compounds, the sisal filler is said to show improved tensile, flexural and impact strengths and better electrical properties, but higher water absorption and lower heat resistance.

Sisal reinforcement has been developed by Irish Ropes Ltd. for applications where plastic mouldings using glass are not justified, but the cheaper sisal (about one-third the cost of glass fibre) may give adequate reinforcement.

Glass Cement for Light Alloys

NEW TYPES OF GLASS are reported to have been developed in work done at the Belorussian Polytechnic Institute. With the use of a charge containing oxides of silicon, boron, aluminium and magnesium, glass was developed which melts at approximately 1,500 deg. C. This new glass, having a coefficient of expansion approximately the same as that of quartz, can stand sudden changes of temperature amounting to 220 deg. C. without cracking.

By using a charge which contains cæsium in addition to boron oxide and lead oxide, a glass was produced which has a coefficient of expansion thirty-two times higher than that of quartz. Glass of this composition melts more readily than aluminium. By adding silicon dioxide to the charge, it is possible to reduce the otherwise high expansion of cæsium. By varying the proportion of silicon, the coefficient of expansion can be controlled to produce glasses with any desired coefficient of expansion. Glasses, with heat expansion coefficient equalling that of aluminium, duralumin, magnesium and other light metals and alloys, can be obtained in this manner. Such glasses can be used as coatings to protect metals from corrosion, as lubricants and coolants in the extrusion of light metals and alloys, and as an adhesive for joining parts made of aluminium and light metals in general.

Butyl Rubber Developments

SHIPBUILDERS are becoming increasingly interested in butyl rubber cables because of the high degree of reliability obtained over long periods of service. They strongly resist oxidation and the action of salt water, oils and solvents, in addition to being remarkably resistant to high and low temperatures. The Royal Mail liner *Loch Loyal* is believed to be the first ship to be wired exclusively with this type of cable, which was supplied by British Insulated Callender's Cables Ltd.

One of the disadvantages of butyl rubber for some applications has been the difficulty of making a satisfactory bond to metals and to other rubbers. A special adhesive has now been developed by the B. F. Goodrich Chemical Co. and marketed as Hycar 2202. The new adhesive, which is known chemically as brominated butyl, also has applications for blending with natural rubber to improve its resistance to ozone and reduce its air permeability to that of the best synthetic rubber.

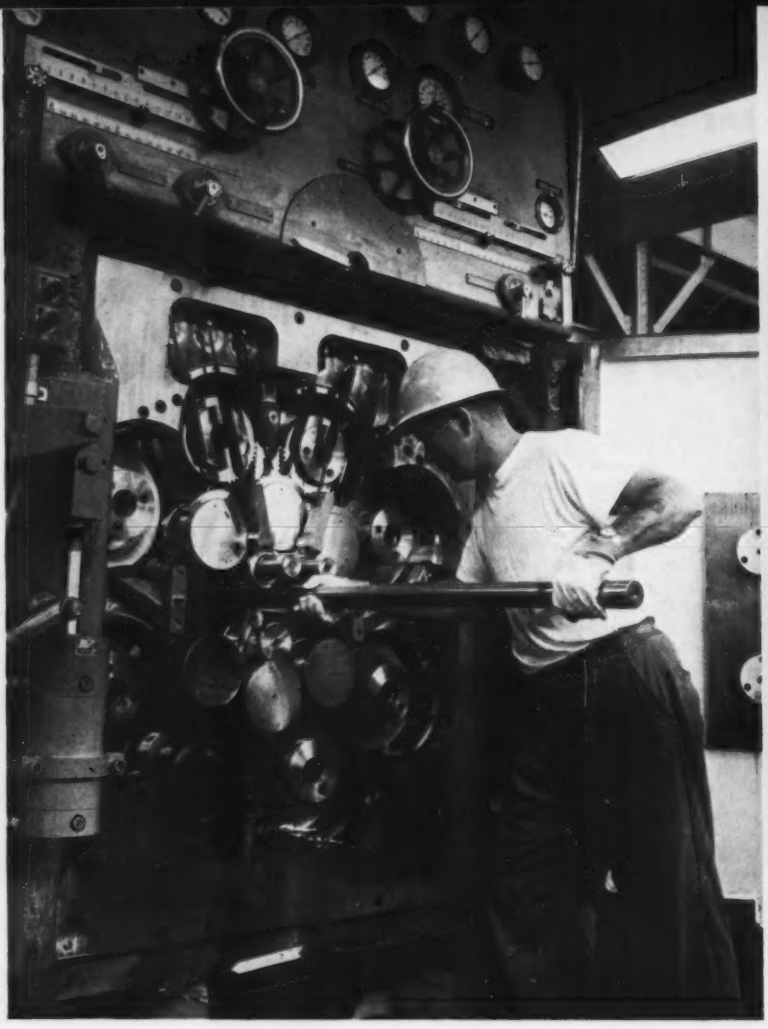
Disc Brakes for Industry

THE MOTOR RACING TRACK is often regarded as the proving ground for new ideas and materials to be used in the motor industry, but the development of disc brakes for racing cars promises to have far-reaching results in much wider fields of engineering. Although originally tried on one or two motor vehicles nearly sixty years ago, it is only recently that the Dunlop Rubber Co. has pioneered the serious use of disc brakes on cars and aircraft.

It has now been announced that Twiflex Couplings Ltd. are developing disc brakes for such industrial applications as overhead travelling cranes and high-inertia machinery. An example of the latter is on one of Dunlop's own rubber mills driven by a 60-h.p. motor where it is claimed that the rollers can be stopped in one-eighth of a revolution. The brakes can be operated by hydraulic, mechanical or electro-mechanical means and a retraction device holds the brake pads clear of the disc, providing automatic adjustment for wear throughout the life of the pads. The friction pads can be quickly renewed by removal of a bolt and are self-centralising, so that a limited amount of shaft end-float can be tolerated.

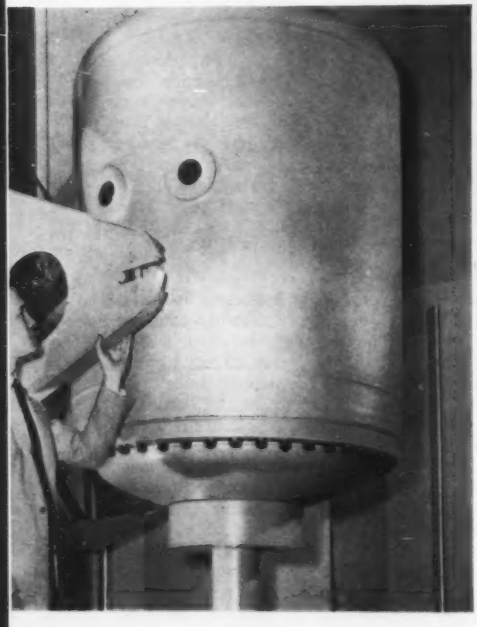
STEEL ROLLING MILL ▶

A total of twenty rolls—two work rolls and eighteen back-up rolls—make up the interior of the 52-in. Sendzimir mill in the new stainless and strip division plant of Jones & Laughlin in the U.S.A. Picture shows an employee changing one of the work rolls on the mill. The mill is the heart of the plant and incorporates the latest techniques for precision rolling and quality control.



ELECTRON ACCELERATOR

The Dynamitron shown here is a new low-cost high voltage electron accelerator developed for sterilising applications in industry and hospitals. It converts large amounts of electrical power into kinetic energy in the form of a beam of high velocity atomic particles. For sterilising purposes, beam penetrating power is estimated at 0·33 cm. per MEV for a material of unit density. It is marketed by the Wilmot Castle Co. of New York.

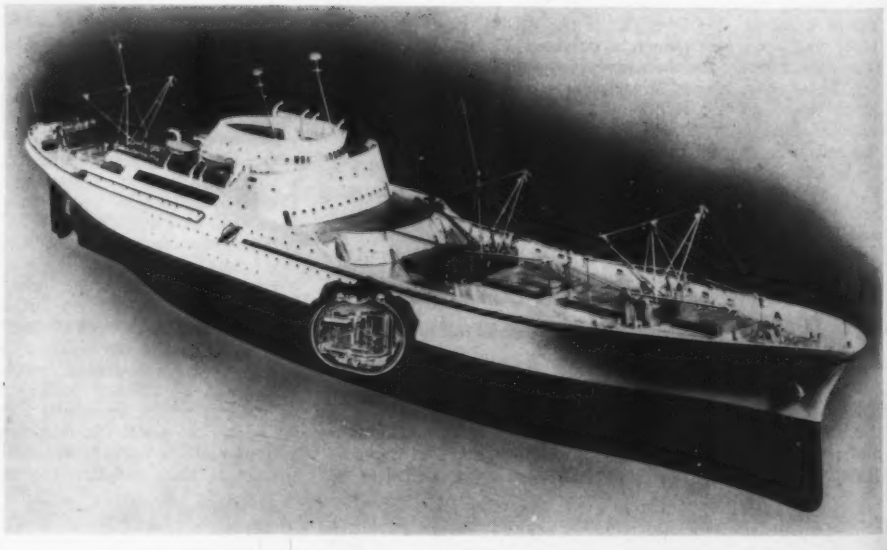


PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN

NUCLEAR MERCHANT VESSEL

Visitors to the recent National Boat Show in London were able to see a model of the world's first nuclear-powered merchant ship, *Savannah*. Now being built in the U.S.A., she is a combined passenger-cargo vessel powered by a pressurised-water reactor, with a maximum rating of 22,000 s.h.p. Propulsion equipment will be a steam turbine connected to a single propeller shaft through double reduction gears. She will be able to operate for three and a half years and 300,000 miles without refuelling.

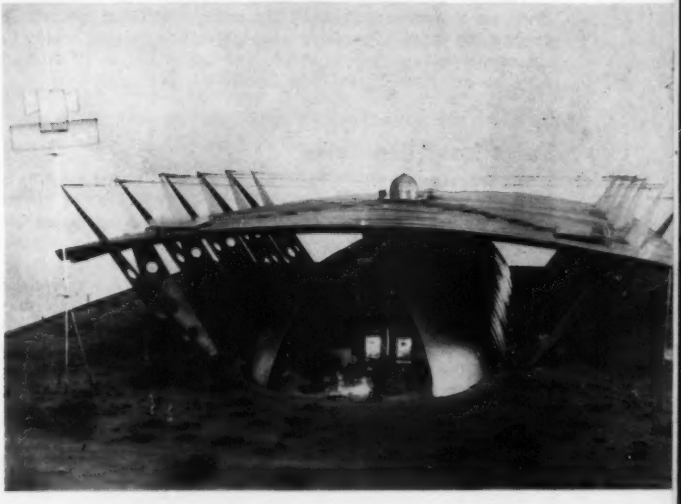


TURBINE ROTOR FROM 150-TON INGOT ▲

This steam turbine rotor, made of high-temperature chrome-nickel-molybdenum-steel, was forged from a 150-ton ingot cast to a special vacuum process by Bochumer Verein, near Dortmund. The diameter of the discs is 4½ ft., the overall length of the rotor is nearly 19 ft. and its finished weight is more than 40 tons.

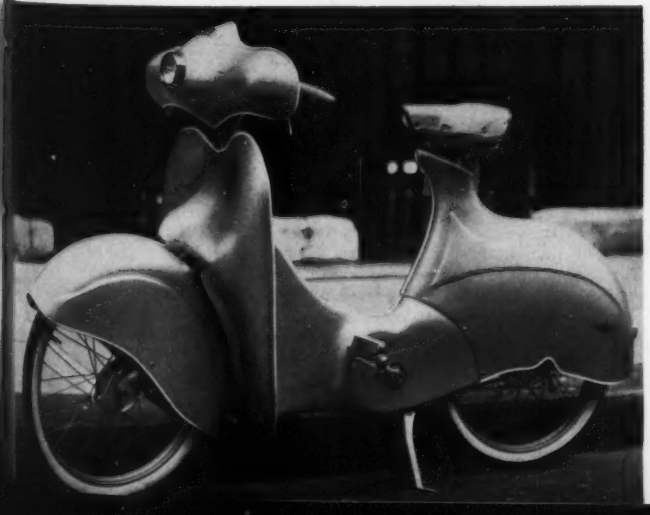
NEW-STYLE DENTAL CHAIR

Benefits for the patient (extra comfort) and dentist (more efficient working positions) are promised for this new dental chair, called the Euphorian Rest Curve Chair, produced by the Ritter Co., of New York. It enables the dentist to perform many operations from a sitting position, thus reducing fatigue. Armrests slide horizontally to allow easy entry to chair. The patient is supported by a single full-length cushion of polyurethane foam, conforming to the shape of a moulded reinforced glass fibre shell.



GLASS FIBRE BICYCLE

Unusually extensive application of glass fibre reinforced plastics material is noted in this new Scoo-Ped pedal cycle which has motor-scooter styling. Fibreglass is used for the easily-removable fairings for chain case, mudguards and legshields.



MOON STRUCTURE DESIGN ▲

Plans for a moon building, built on a sea of dust particles, and providing living quarters and space for research laboratories, space vehicle maintenance bays and facilities for communication with the earth, have been drawn up by the Wonder Building Corp., of Chicago, under the direction of Prof. J. S. Rinehart, of the Colorado School of Mines. The design takes into account expected problems of meteorite bombardment, low gravity, fluctuating temperature, intense ultra-violet rays and many other aspects.

Flow-brightened Tin Coatings

THE CHASSIS of electronic equipment are usually made of sheet steel for strength and cheapness, but they must be made resistant to corrosion while remaining easy to solder. The corrosion problem is becoming increasingly important with the steep rise in exports of equipment to tropical countries, but at the same time there has also been an increase in the use of soldered joints, particularly for T.V. chassis. A simple and cheap way to meet the problem of soldering is to use tinplate, but the large number of holes required for the components leaves the steel exposed at many points.

The Tin Research Institute announce that one of the leading German manufacturers of radio and television sets has carried out long-term corrosion tests on the East African coast and these have shown that flow-brightened tin coatings were the least affected by corrosion. This is a significant result in view of the fact that comparison was made with lacquer, galvanised, cadmium, tin-zinc and matte tin coatings.

Titanium Developments

NEW ALLOYS and new applications of titanium are still receiving attention from producers, particularly in the U.S.A. One of the latest products which is of special interest is an all-titanium flexible tubing of 0·05 in. inside diameter, made by Flexonics Corp. It is reported to be ideally suited where a capillary casing is required at elevated temperatures or in corrosive conditions.

Also in the U.S.A., Mallory-Sharron Metals Corp. have produced a new high-strength titanium alloy which, for long periods at temperatures of 600 deg. C., is superior to many alloy steels. This titanium, known provisionally as MST.881, contains 8 per cent Al, 8 per cent Zr and 1 per cent combined tantalum and columbium. For short periods a considerable degree of strength at 820 deg. C. can be maintained.

Titanium castings are also being produced by two American firms on a commercial basis. By using special compounds in expendable moulds precision castings with consistent mechanical properties are now possible, and a fine degree of control may be exercised to exclude deleterious contaminations.

Swiss Insulation Guide

THE INTERNATIONAL ELECTROTECHNICAL COMMISSION is currently considering the preparation of an encyclopædia aimed at providing the electrical designer with a handbook giving the properties and behaviour of the many insulating materials now available. The Swiss Electrotechnical Committee has, however, already gone ahead and published its own *Encyclopædia of Electrical Insulating Materials*, containing design information which is presented in condensed form in tables and indicating physical and chemical properties by graphical symbols. The encyclopædia, published in French, gives information on the behaviour of various materials under operating conditions and precautions to be taken in application.

IN NEXT MONTH'S ISSUE . . .

Principal features is the May issue of

ENGINEERING MATERIALS AND DESIGN will include:

Rigid Thermoplastics in Engineering
Comparison of p.v.c., polystyrene and polyethylene.

Economics and Characteristics of Diecast Components
Advantages and properties of diecasting alloys.

Selection of Pneumatic Actuators
A survey and guide to the extensive range available.

Structural Problems at Elevated Temperatures
Review of kinetic energy problems in practical design.

Noise—its Nature, Behaviour and Reduction
Second of two articles on its elimination and prevention.

Journal Boxes Use Neoprene Sponge

THE DU PONT ORGANISATION claims to have overcome the problem of "waste grab" in journal boxes by the use of a neoprene sponge lubricator. Trouble has been experienced in the U.S.A. with the cotton waste packing being carried up between the bearing and the axle on rail wagon journal boxes, causing the bearing to run hot. By designing a neoprene sponge saddle which rubs on the underside of the journal, adequate lubrication can be provided without danger of shredding. Felt wicks terminate in the sponge feeding oil from a reservoir. The neoprene is said to retain its resilience and strength for several years under these conditions.

Heat- and Abrasion-resistant Paints

THE NEED FOR PAINTS which show a high degree of resistance to heat and abrasion is apparent not only for military purposes but in many industries. A report recently issued in the U.S.A. by the Rock Island Arsenal indicates the results of a particular series of tests to evaluate the resistance of various paints to deterioration by heat from blast flame and abrasion by sand, with a view to their suitability for rocket launchers and similar equipment.

Coatings were applied to about the same extent on aluminium and steel panels, and examinations after the tests showed ceramic-type coatings to be excellent for heat and abrasion resistance. Coatings of p.t.f.e. were also found to be resistant to heat and abrasion and, although the results at this stage cannot be considered conclusive, these coatings are probably more difficult to apply than the ceramic, silicone or dibutyl titanate coatings. Epoxy-type coatings were not promising as a heat- and abrasion-resistant coating as suggested by tests on two panels.

The application of ceramic-type coatings should offer no difficulties, since no special cleaning, etching or other preparation was necessary. No primers were used, although it was considered that it might be advisable to use zinc dust pigmented primers if possible. Excellent heat and abrasion test results were obtained with a zinc dust pigmented dibutyl titanate paint. Ceramic-type coatings which can be applied with standard paint spray equipment appear to be superior to either silicone or dibutyl titanate type coatings.

Stainless Braid Helps Casting Design

A PATENTED casting process used by the Howard Foundry Co. in the U.S.A. permits the design of intricate internal passages in magnesium castings and thereby reduces subsequent machining. A further advantage claimed is that it reduces trapped gases caused by the use of cores containing organic bonding materials.

The process involves the use of cores made by slipping stainless-steel braid over copper tubing. After the casting has been poured and cooled, the copper is dissolved out and the braid removed. The braid is strong and flexible enough for a $\frac{3}{8}$-in. diameter braid to be pulled out of an $\frac{1}{4}$-in. diameter hole. This process opens up new possibilities for the coring of passages for lubricating, hydraulic or cooling purposes in a limitless number of ways, including branched holes. The reduction in voids caused by gassing is said also to result in a greatly increased yield of sound castings.

Call for New Altimeter Design

THE DESIGN of altimeter faces in aircraft is to be the subject of a special study ordered by the Ministry of Transport and Civil Aviation. A committee has been set up to investigate the introduction of a face and mechanism which reduces the possibility of ambiguity, following incidents in which pilots are reported to have misread the altimeter by 10,000 ft.

The new requirements apply to aircraft flying higher than 20,000 ft., and operators have been informed by the Air Registration Board that new faces must be fitted by the end of September. Organisations representing operators, pilots, navigators, as well as instrument and aircraft manufacturers, have been invited to appoint delegates.

On a new face which has been recommended, the 10,000-ft. pointer will be more conspicuous, being of greater length and different shape.

Engineering Materials and Design

THE METRIC SYSTEM FOR BRITAIN?

IF engineering designers have anything to say for or against the abolition of our present system of measurement and the adoption of the metric system in its place, now is the time for them to express their views, for discussions are taking place which may, apart from their very important political and economic implications, profoundly influence future engineering design. No doubt some designers will wave aside the suggestion that any change is likely to take place, and one must admit that they have some fairly strong arguments on their side. A Royal Commission examined the metric system as long ago as 1867, and ever since there have been intermittent bursts of enthusiasm for it.

Since 1951, however, events have taken place which lead one to believe that a decision regarding the metric system may not be very far away, and it is well that designers should be fully aware of what is happening and what the general adoption of the metric system would mean to them. The "Report of the Committee on Weights and Measures Legislation" in 1951—known as the Hodgson Report—suggested that there is a certain "inevitability" about the adoption of the metric system in this country, and that before any change is made there should be agreement about it with the Commonwealth and the U.S.A. Since then the matter has been discussed once or twice in Parliament, and last year the British Association for the Advancement of Science formed a committee to follow up the Hodgson investigation by attempting to obtain more detailed facts about the situation.

At about the same time as the British Association's action, the matter came up for discussion at the Association of British Chambers of Commerce. Quite independently, they set up a panel to investigate the metric system and two committees are now working together. These committees have produced a number of questionnaires for submission to the larger firms in industry, the trade associations and the learned societies. They are also taking up the matter with Government departments, nationalised industries and the commercial attachés in foreign countries. The results of all this effort will naturally take time to analyse and the committee's report is expected later this year.

A great deal of argument has been put forward about the relative merits of the metric and the imperial systems. Some people say we cannot afford to change, others that we cannot afford not to change; but obviously the biting question is, what would it cost to change and what would be the advantages on a cost basis when we have changed?

Apart from the mathematical simplicity of the metric system and the fact that it is used internationally for scientific work, it has important advantages commercially. Trade in engineering products between imperial and metric countries is growing and many manufacturers would benefit greatly by using the same system for home and export markets.

However, one of the biggest difficulties in a change-over would be the attempt to adapt engineering equipment and products from inch size to metric. This problem arises because the generally accepted conversion factor of 1 in. = 2·54 cm. very rarely works out to a finite dimension with a reasonable number of decimal places when converting from a recognised inch size. The result is usually an awkward metric number, and the tendency is to round this off to a convenient one. If there are tolerances on the inch and metric dimensions and rounding off has taken place, a shift of size may occur so that the parts may not be interchangeable if close fits and tolerances are required.

An investigation by the International Standards Organisation showed that in the manufacture of nuts and bolts something like 80 per cent of the world's production was in inch sizes, considerable weight being put into this category by the enormous production in the United States. However, what was really surprising was that three years ago many metric countries were producing half their nuts and bolts in inch sizes.

It is easy to think that if Britain adopted the metric system costs of production would fall, but there would be heavy transitional costs over a period which might be of the order of twenty years. Therefore, it must follow that even if there were ultimately a reduction in costs of production and prices, there would be a difficult interim period when prices would rise. Conversely, if we removed from the metric countries the need for producing equipment in inch sizes (which they produce to sell in the U.K., the U.S.A. and the Commonwealth) they would undoubtedly benefit by reduced costs of production. From this it would follow that they could reduce their prices at a time when we had to increase ours. We must remember that our six best export customers, which account for one-third of our total export trade, include only one metric country (i.e., India, now in process of changing over).

Technical progress in industry is ever moving towards the unification of standards and if the Hodgson report has forecast correctly the future trends, then the sooner the change-over to metric is started the better. Such a change-over will involve immense capital expenditure, but this objection can be to some extent overcome if the re-tooling of industry is spread out over a long enough period to coincide with normal replacements due to obsolescence.

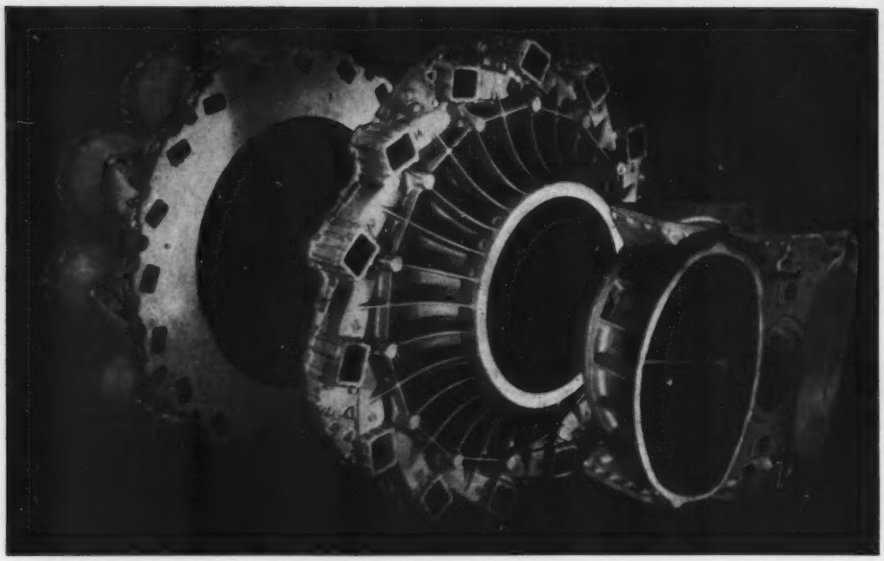


Fig. 1. Complex castings in ZRE1 magnesium alloy for the de Havilland Ghost gas turbine engine.

DESIGNING WITH MAGNESIUM ALLOYS

Magnesium's industrial value has been exploited only in comparatively recent times. This article examines the properties of the metal and other factors affecting modern product design

by K. G. BAILEY*

MAGNESIUM is the eighth most abundant element and the sixth most abundant metal in the earth's crust, where it is present to the extent of 2·2 per cent. Sea water contains 0·13 per cent of magnesium metal so that one cubic mile of sea water contains over five million tons of metal.

Despite the availability of eight magnesium bearing minerals, of which dolomite is the most abundant, by far the largest tonnage of magnesium is today extracted from sea water.

Of the many extraction processes employed, by far the greatest output has been obtained from electrolysis of the molten chloride. Thermal reduction of dolomite by ferro-silicon occupies second place.

Like most other metals, pure magnesium is not sufficiently strong to be of any value for engineering purposes, although it is used widely as an alloying element with other metals. By the addition of comparatively small quantities of selected elements, however, alloys of magnesium can be produced whose mechanical properties are enhanced and, when considered in conjunction with their light weight and ease of machinability, make them attractive to engineering designers.

Prior to 1945 the most widely-used alloying elements were aluminium, zinc and manganese: aluminium and zinc as hardening agents to improve the strength properties, and manganese to improve resistance to corrosion. These alloys, containing 8 or 9 per cent aluminium, 0·4 per cent zinc, are still fairly widely used today.

After World War II it was found that none of the established alloys could meet the demands of the airframe or turbine-engine designers for higher strength at normal and elevated temperatures, or resistance to creep for the new generation of aircraft and gas turbine engines.

This led to the development and production in the U.K. of the magnesium-zinc-zirconium alloys possessing in cast form proof stresses nearly double those of the original alloys. The high test bar properties realised are often reached and even exceeded in pieces cut from actual castings. The alloys also show much reduced notch sensitivity in fatigue.

Additions of the rare earth metals to the magnesium-zirconium base gave a range of easily castable alloys which combine excellent high-temperature properties and complete freedom from porosity. The soundness of the casting is such that, despite the higher price, these alloys are often used for applications at normal temperatures where complete pressure tightness and freedom from porosity are essential.

The discovery that thorium has a beneficial effect on the creep resistance of magnesium alloys led to the simultaneous development in the U.S.A. and the U.K. of an important range of alloys of the magnesium-zirconium-zinc-thorium system. Outstanding examples are ZT1 with greatly improved creep resistance at temperatures up to 350 deg. C. (providing an alloy now widely used in both British and American turbine engines), and TZ6, a structural alloy having even higher normal temperature

* *Development manager, Magnesium Elektron Ltd.*

properties than Z5Z but with the additional advantages of weldability and increased soundness.

A more recent development in the field of cast structural alloys is that of the magnesium-silver-rare earth-containing alloys where strength properties equal or exceed those of the high-strength aluminium casting alloys.

Development of wrought magnesium alloys containing thorium for use at elevated temperatures and designed principally for use in guided weapon structures is well advanced. Such alloys are available in sheet form in commercial quantities in the U.S.A. Similar alloys, but without the need for prior and complex heat treatments associated with the American product, are also available in this country.

The physical properties of magnesium alloys are listed in Table 1. Lightness is the most outstanding and attractive quality of magnesium. Its specific gravity, 1·76-1·83, is best remembered as approx. 1 oz./cu. in.

The mechanical properties are listed in Table 5. The following are some specific properties, examined in their relationship to design.

Structural Design Properties

TENSILE PROPERTIES—The tensile properties are still the most common criteria for the comparison of structural metals. Based on equal weight, the tensile properties of magnesium alloys, and particularly those of the very fine-grained zirconium-containing alloys, compare well with those for other metals. This is illustrated for some representative wrought and cast alloys in Figs. 5 and 6. In Figs. 5a and 6a the stress/strain relationship of the various alloys is plotted in the conventional manner, whereas in Figs. 5b and 6b the scales for stress are in inverse ratio to the densities. This has the effect of making the elastic portions of the curves practically congruent in spite of the actually differing Young's Modulus of the materials concerned and is therefore indicative of their strength/weight characteristics.

MODULUS OF ELASTICITY—The "E" value of magnesium is about $6{\cdot}5 \times 10^6$ p.s.i., which compares with about 10×10^6 p.s.i. for aluminium and about 30×10^6 p.s.i. for steel. In consequence, it is necessary to stiffen parts which in steel or aluminium have been stressed to a given limit of deflection. In castings such a necessity will seldom arise, because for practical reasons castings usually have much thicker walls than are required by the stresses or deflection involved. In structural components made from wrought magnesium, however, it will usually be necessary to design with larger moments of inertia than would be employed with other metals in order to compensate for the lower modulus. Since the moment of inertia of a section, and therefore its stiffness, increases in proportion to the cube of its depth, and only in linear proportion to its width, it is clear that, wherever possible, the compensation for the lower modulus should be achieved by increasing the depth of the section in order to obtain maximum weight-saving.

Magnesium alloys permit weight savings of about 65-70 per cent and 20-25 per cent respectively against steel and aluminium when comparing rectangular bars of equal width but differing depth (see Fig. 8).

The low modulus of magnesium has also to be considered in stressed compound components consisting of magnesium and, say, steel, in which case the material with the higher modulus will for a given deflection be stressed to a correspondingly higher extent.

BENDING STRENGTH—Limitation of deflection as a design requirement has already been dealt with. If, in parts which

Fig. 2. *Above.* Pressure die-cast magnesium crankcase and gear-box for the Fitchtel & Sachs 47-c.c. two-stroke engine, comprising four castings.

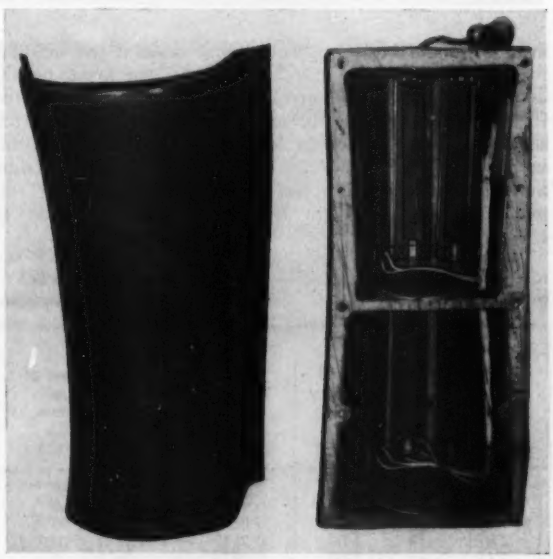


Fig. 3. *Above right.* Air intake stretch pressing for the Folland Gnat. Also shown are details of male tool with electric heater elements.

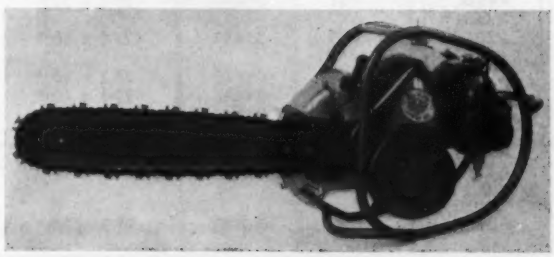


Fig. 4. *Right.* Sankey P54 portable chain saw—nine magnesium alloy die-castings.

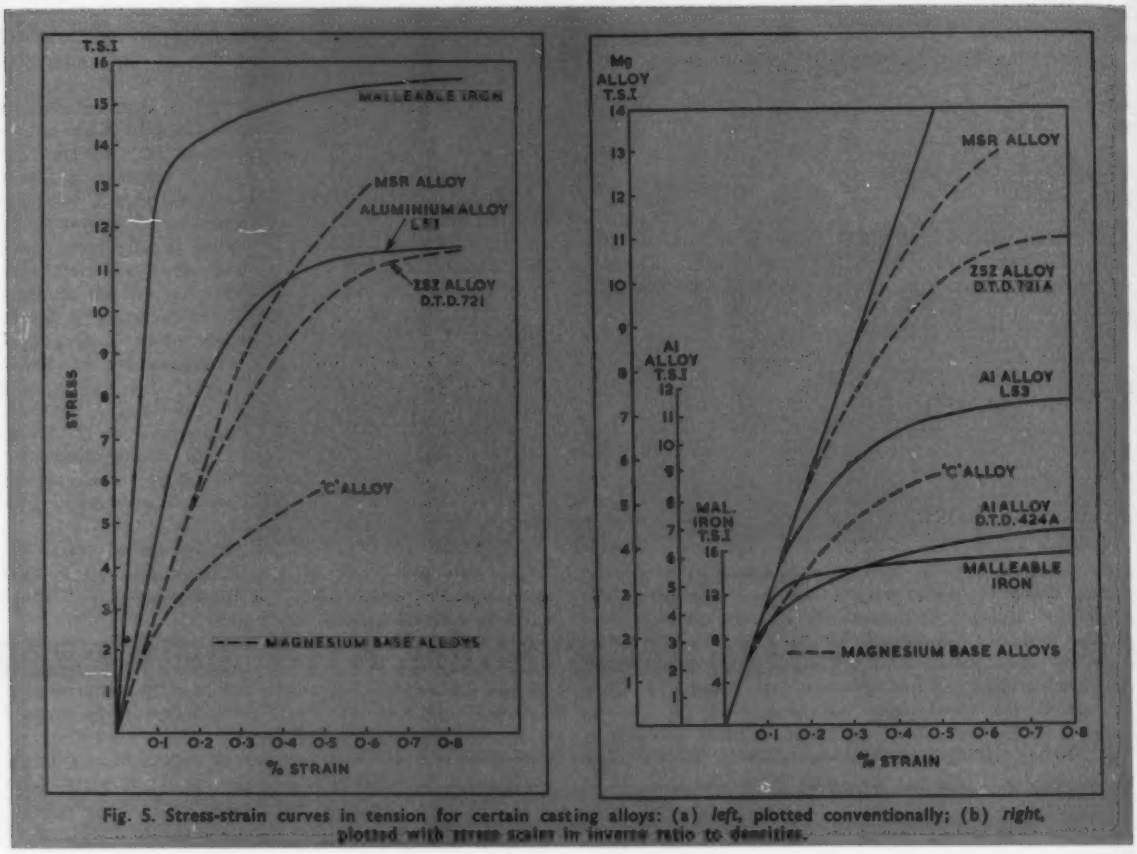


Fig. 5. Stress-strain curves in tension for certain casting alloys: (a) *left*, plotted conventionally; (b) *right*, plotted with stress scales in inverse ratio to densities.

are stressed in bending, the bending stress is the limiting factor, compensation must be made for the lower tensile and compressive proof stresses (or whatever other figures form the basis for the permissible stress) compared with stronger, heavier materials. This is done by increasing the section modulus of the part in question. Since the section modulus increases with the square of the depth of the section, weight will still be saved if compensation is effected in this way.

DAMPING CAPACITY—The damping capacity of a material is its ability to absorb and dissipate energy into heat when subjected to cyclic stresses below the endurance limit. A high damping capacity is usually associated with a low elastic modulus, so that magnesium alloys have in most cases better damping capacity than aluminium alloys and are much better than steel. By tending to limit the intensity of vibrations, this property reduces stress, improves service life and permits quieter operation. Fig. 14 compares the

TABLE 1. Physical properties of some magnesium alloys

Alloy	Density (g/cm³) (20°C.)	Weight lb./cu. in.	Coefficient of Thermal Expansion (per °C.) (20–200°C.)	Thermal Conductivity (C.G.S. Units) (20°C.)	Electrical Conductivity (mho–cm²) (20°C.)	Electrical Resistivity (ohm–cm²) (20°C.)	Specific Heat (cal./g/°C.) (20–100°C.)
Z5Z	1·81	0·0652	$27·3 \times 10^{-6}$	0·27	$15·2 \times 10^{4}$	$6·6 \times 10^{-6}$	0·23
RZ5	1·84	0·0660	$27·1 \times 10^{-6}$	0·27	$14·7 \times 10^{4}$	$6·8 \times 10^{-6}$	0·23
TZ6	1·87	0·0675	$27·1 \times 10^{-6}$	0·27	$15·2 \times 10^{4}$	$6·6 \times 10^{-6}$	0·23
ZRE1	1·80	0·0647	$26·8 \times 10^{-6}$	0·24	$13·6 \times 10^{4}$	$7·3 \times 10^{-6}$	0·25
ZT1	1·83	0·0657	$26·7 \times 10^{-6}$	0·25	$13·8 \times 10^{4}$	$7·2 \times 10^{-6}$	0·23
A8 (as cast)	1·81	0·0652	$27·2 \times 10^{-6}$	0·20	$7·5 \times 10^{4}$	$13·4 \times 10^{-6}$	0·24
AZ91 (as cast)	1·83	0·0657	$27·0 \times 10^{-6}$	0·20	$7·1 \times 10^{4}$	$14·1 \times 10^{-6}$	0·24
C	1·81	0·0652	$27·2 \times 10^{-6}$	0·20	$7·5 \times 10^{4}$	$13·4 \times 10^{-6}$	0·24
ZW3	1·80	0·0647	$27·1 \times 10^{-6}$	0·30	$18·2 \times 10^{4}$	$5·5 \times 10^{-6}$	0·23
ZW1	1·80	0·0647	—	—	—	—	0·23
ZW6	1·83	0·0657	$26·0 \times 10^{-6}$	0·28	$16·7 \times 10^{4}$	$6·0 \times 10^{-6}$	0·25
AM503	1·76	0·0633	$26·9 \times 10^{-6}$	0·34	$20·0 \times 10^{4}$	$5·0 \times 10^{-6}$	0·25
AZ31 (high purity)	1·78	0·0640	$26·0 \times 10^{-6}$	—	$10·0 \times 10^{4}$	$10·0 \times 10^{-6}$	0·25
AZM	1·80	0·0647	$27·3 \times 10^{-6}$	0·19	$7·0 \times 10^{4}$	$14·3 \times 10^{-6}$	0·24

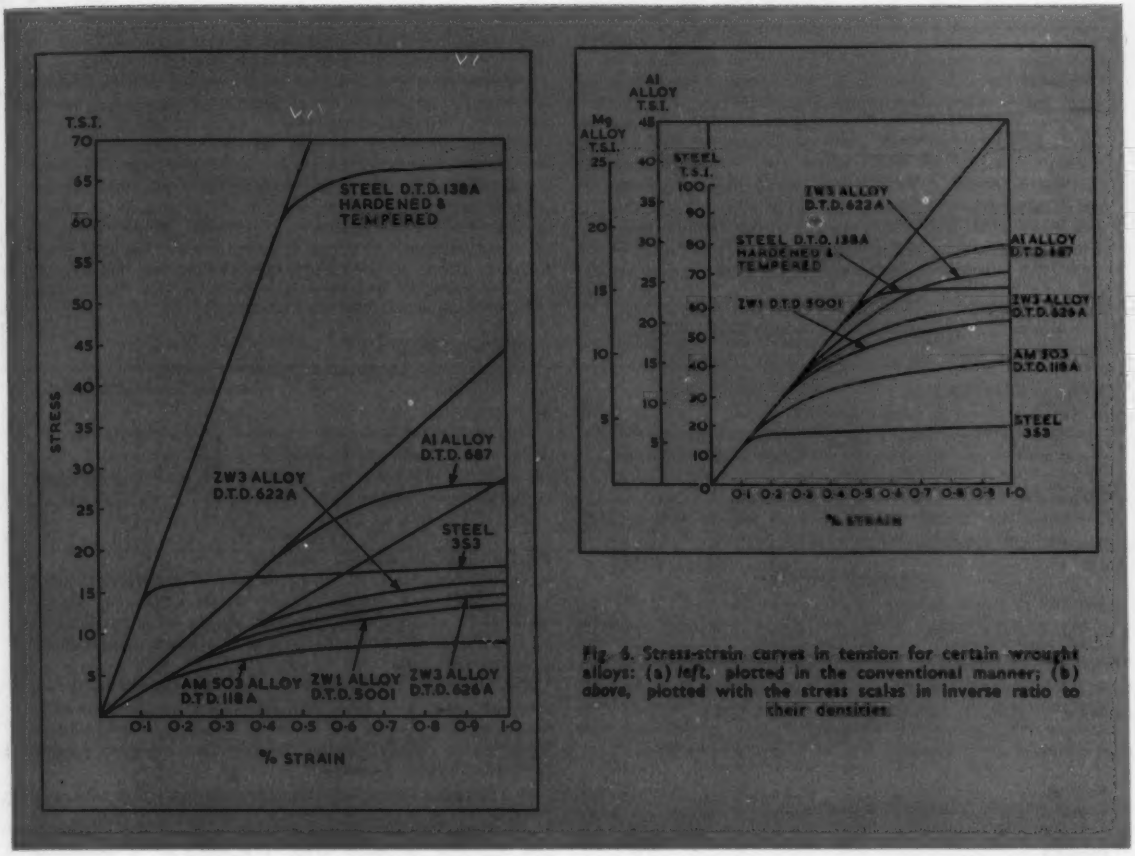


Fig. 6. Stress-strain curves in tension for certain wrought alloys: (a) *left*, plotted in the conventional manner; (b) above, plotted with the stress scales in inverse ratio to their densities.

approximate damping data for some magnesium alloys with those for aluminium alloys and cast iron, based on British and U.S. test results.

Another property associated with low elastic modulus is resilience, which is the capacity of a material for shock absorption within the elastic range. The high resilience of magnesium recommends its use in lightweight components where good capacity for shock absorption is an important requirement.

RESISTANCE TO FATIGUE—As can be seen from Table 5, magnesium alloys have good fatigue resistance, and in the case of the zirconium-containing alloy Z5Z and the thorium-containing alloy TZ6 approximately the same values have been obtained on both notched and unnotched specimens. These alloys therefore show remarkably low notch sensitivity and are specially recommended for castings subjected to fatigue stress. The other magnesium alloys, including the wrought alloys, are, like most metals, more notch sensitive. Since in practice fatigue resistance is lowered by notches, abrupt changes of section and other stress-raising factors, the designer should aim to avoid or reduce these as far as possible.

S/N curves for a typical "commercial" alloy (A8) are given in Fig. 15.

IMPACT STRENGTH—The notched bar impact values of magnesium alloys are low in comparison with those of the heavy metals such as bronze, copper and mild steel.

(*continued on page 192*)

Fig. 7. Deep-drawn part made with one stroke in a single die, by Brooks & Perkins Inc.

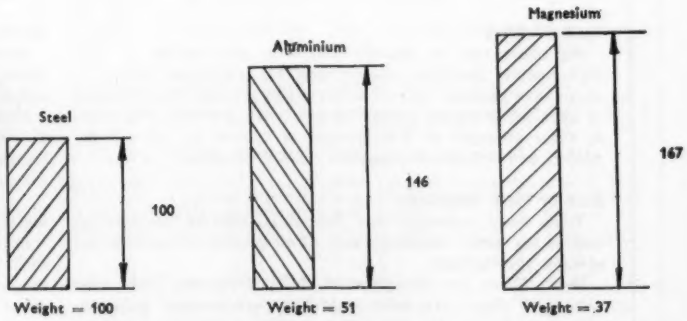


Fig. 8. Weight saving of magnesium against steel and aluminium rectangular bars of equal rigidity.

TABLE 2. Component production with magnesium alloys

FOUNDRY METHODS

Sand Casting

In regular production from a few ounces to 1,500 lb. Very complex shapes possible. Wall thickness for average casting, $\frac{5}{32}$-$\frac{3}{16}$ in. Extra-thin walls produced cheaply by acid etching. Cast-steel or yellow metal bushes and inserts can be cast in where necessary for strength. Anti-friction bearings can be fitted using interference fits 0·0005-0·001 in./in. of dia., i.e. 50 per cent more than for aluminium. Cast Mg has good bearing properties (e.g., Volkswagen and D.H. Gipsy Queen camshafts run in bare Mg).

Gravity Casting

Superior to sand casting for strength and accuracy. Less machining needed.

Pressure Die-casting

Wall thicknesses about one-half those in similar sand castings. Maximum weight savings and economy possible for mass production runs. Nearly same tolerances as for zinc.

Other Castings

Plaster mould, shell mould, precision and investment casting methods are employed to a lesser extent.

CHIPLESS FORMING

Forging

Higher and more uniform mechanical properties possible than with castings. Suitable for heavily stressed parts for fatigue and impact, or where there is space limitation. Mg alloys can be forged with hammers, mechanical presses or hydraulic presses. Strongest alloys forged slowly on hydraulic presses. High properties obtained in hammer forgings and mechanical press forgings, the latter to close limits.

Rolling

Rolled sheet and plate is available.

Forming

Carried out hot at 230-350 deg. C.; only very simple operations possible at low temps. Additional lattice slip planes available for plastic deformation above 225 deg. C.[2] Rubber pressing is possible.[3] Even below 225 deg. C., heating improves forming.

Advantages of hot forming include:

1. Greater deformation in one operation than for other metals, eliminating inter-annealing operations.
2. Power requirements reduced.
3. Springback is reduced as forming temperatures are increased. Dimensional accuracy is more easily attained. for effect of short-time pre-heating, see Fig. 13. For examples of hot forming techniques, see Fig. 1. Heat-resisting lubricants are necessary.

Impact Extruding

Process is carried out hot.

Hot Extrusion

Mg alloys are extruded into any of the shapes seen in aluminium, often using same dies. Hollow sections, both symmetrical and irregular, give maximum structural efficiency with minimum weight and cost.

MACHINING

Turning, Milling, Routing, Drilling

Mg has excellent machinability which permits operations at extremely high speeds—usually at the maximum possible of modern machine tools. Heavier depths of cut and higher feed are possible with excellent surface finish nearly always without lubricants.

Tipped tools are preferable, but high-speed tools are normally suitable. Rake and clearance angles generally increased and number of teeth in milling cutters reduced. Since Mg in finely divided form is inflammable, suitable precautions must be taken.

Tapping

When tapping fine thread or drilling holes with unfavourable diameter to depth ratio, a mineral oil is sometimes used.

TABLE 3. Magnesium fabrication and assembly

WELDING[4]

Oxy-acetylene

Can be used for the aluminium- and zinc-containing alloys but not for those containing zirconium. Gas welding requires a special flux to remove the oxide film. As the flux residues are corrosive, the assembly must be thoroughly washed in hot water.

Arc Welding

Argonarc is recommended for all the magnesium alloys. The use of flux is avoided and it is not necessary to design parts for ease of flux removal. Heat input for both gas and electric methods is slightly lower than for the aluminium-rich alloys.

Spot Welding

Mg alloys can be electric resistance spot welded by the high-capacity machines usually used for aluminium alloys, if these have positive control of the welding cycle. The strength of spot welds varies almost linearly with material thickness. A shear strength of 350 lb./spot is typical for 16 S.W.G. AM503 and 450-500 lb./spot for 16 S.W.G. ZW1.

Butt or Flash Welding

Trials have indicated that the metal can be successfully welded by these methods, but development is needed for specific applications.

Note: With the exception of ZSZ, ZW3 and ZW6, the zirconium alloys are fully weldable. Interwelding between castings and wrought materials is possible with certain alloys. Of the alloys which do not contain zirconium, AM503 and AZM are fully weldable, the argonarc process being preferred to gas welding. Casting alloys A8, AZ91 and C can be repair-welded by the argonarc process, and structural welds can be made casting-to-casting or to wrought AZ31 alloy. Gas welding should be confined to AM503 and AZM.

Stress Relief

At 250 and 350 deg. C., according to composition.

JOINING METHODS

Riveting

Rivets must be of the Al 5 per cent Mg type (B.S. 1473 NR6). Pure Al rivets may be used where shear loading is small. The small closing pressures required lessen risk of damage.

Bolting and Screwing

Bolts and screws best if cadmium-plated steel. Coarse threads better if screwed into Mg. Precautions necessary to avoid water entrapment or accumulation.

Note: Insulation is necessary when Mg alloys are fastened to wood or other metals to prevent electrolytic corrosion. Suitable insulators are plastics, chromate compounds, rubber compounds, lacquers, certain glues and aluminium foil.

Bonding

In the U.S.A., mixtures of resins with synthetic rubber, such as Metlbond, Cycleweld or Pliobond, are extensively used. In the U.K., stronger bonds, using epoxy resins and other thermosetting compounds such as Araldite and Redux, are widely employed. Bond strengths not as great with Mg-rich alloys as with aluminium, though adequate for all but highly stressed applications. Bonded joints exclude water.

TABLE 4. Protective treatments for magnesium[5]

Properties

Mg alloys similar to mild steel for most purposes. Readily tarnished by damp atmospheres, but not otherwise corroded. Industrial atmospheres, especially dusty ones, in general cause little more than slight surface attack. Intercrystalline corrosion unknown in Mg alloys. Lodgment of water, particularly acid or salt, is to be avoided particularly when Mg alloy is in contact with steel or brass. Galvanic corrosion only possible in presence or an electrolyte. Grease, primers and sealing compounds help to prevent liquid reaching joint. Severe conditions demand: (1) careful design to avoid moisture entrapment, (2) suitable treatment scheme for environment, and (3) careful assembly to prevent lodgment of moisture in crevices. Mg alloys are resistant to all common petroleum-base fuels and oils.

Painting

Mg alloys may be painted in usual manner. Best done after passivating by chromating. A priming coat containing a chromate is usual. Stoving paints better than air drying; high-temperature epoxy lacquers best.

Chromating

This process passivates the surface of Mg alloys so that the surface is unchanged for a reasonable period. Good base for painting. Various baths available. Acid chromate bath is a rapid dip process for rough castings. Chrome manganese bath, not affecting machined tolerances, takes longer.

TABLE 5. Typical mechanical properties and chemical composition of some representative magnesium alloys

Typical Chemical Composition						Elektron Alloy	Specification	Tensile Properties			Compressive Properties		Fatigue Endurance Value (50×10^6 reversals)	
Al (%)	Zn (%)	Mn (%)	Zr (%)	Rare Earth Metals (%)	Th (%)			0·1% Proof Stress (t.s.i.)	Ultimate Stress (t.s.i.)	Elongation (% on 2 in.)	0·1% Proof Stress (t.s.i.)	Ultimate Stress (t.s.i.)	Unnotched (t.s.i.)	Notched (t.s.i.)
CASTING ALLOYS														
STANDARD STRUCTURAL ALLOYS														
8·0	0·5	0·3				A8 As cast	B.S. L121	4·5-5·5	9·0-11·0	2- 5	4·5- 5·5	18·0-22·0	5·0-5·5	3·7-4·2
						A8 As cast	B.S. 1277	4·5-5·5	9·0-11·0	2- 5	4·5- 5·5	18·0-22·0	5·0-5·5	3·7-4·2
						A8 Solution treated	B.S. L122	4·5-5·5	13·0-17·0	6-15	4·5- 5·5	21·0-27·0	5·0-5·7	4·0-4·5
						A8 Solution treated	B.S. 1278	4·5-5·5	13·0-17·0	6-15	4·5- 5·5	21·0-27·0	5·0-5·7	4·0-4·5
9·5	0·5	0·3				AZ91 As cast ...	B.S. L123	4·5-6·0	8·0-10·5	1- 3	5·0- 6·5	18·0-22·0	5·0-5·5	3·7-4·2
9·5	0·5	0·3				AZ91 As cast ...	B.S. 1273	4·5-6·0	8·0-10·5	1- 3	5·0- 6·5	18·0-22·0	5·0-5·5	3·7-4·2
9·5	0·5	0·3				AZ91 Solution treated	B.S. L124	4·5-6·0	13·0-16·0	4- 8	4·5- 6·5	22·0-28·0	5·0-6·0	4·2-5·0
9·5	0·5	0·3				AZ91 Solution treated	B.S. 1274	4·5-6·0	13·0-16·0	4- 8	4·5- 6·5	22·0-28·0	5·0-6·0	4·2-5·0
9·5	0·5	0·3				AZ91 Fully heat-treated	B.S. L125	6·5-8·5	13·0-16·5	1- 4	6·5- 8·5	25·0-30·0	4·5-5·0	3·7-4·0
9·5	0·5	0·3				AZ91 Fully heat-treated	B.S. 1275	6·5-8·5	13·0-16·5	1- 4	6·5- 8·5	25·0-30·0	4·5-5·0	3·7-4·0
7·5-9·5	0·3-1·5	0·15 min.				C As cast	—	4·0-5·5	8·0-11·0	2- 5	4·0- 5·5	18·0-22·0	4·7-5·2	3·7-4·2
7·5-9·5	0·3-1·5	0·15 min.				C Solution treated ...	—	4·0-5·5	12·0-16·0	4-10	4·5- 5·5	21·0-27·0	5·0-5·5	4·0-4·7
7·5-9·5	0·3-1·5	0·15 min.				C Fully heat-treated ...	—	5·0-7·5	12·0-16·0	1- 3	5·5- 7·0	22·0-28·0	4·0-4·7	3·7-4·0
ZIRCONIUM-RARE EARTH AND ZIRCONIUM-THORIUM CONTAINING STRUCTURAL ALLOYS														
	4·5		0·7			Z5Z As cast	D.T.D. 711a	7·0- 8·5	13·0-17·0	7-15	7·0- 8·0	22·0-24·5	4·7-5·2	3·7-4·2
	4·5		0·7			Z5Z Heat-treated ...	D.T.D. 721a	8·5-10·5	15·0-18·0	5-12	9·0-11·0	23·0-27·0	4·5-5·5	4·5-5·5
	4·0		0·7	1·2		RZ5 As cast	D.T.D. 738	5·5- 6·5	11·0-12·0	3- 6	6·0- 7·5	20·0-22·0	5·0-5·5	3·2-3·7
	4·0		0·7	1·2		RZ5 Heat-treated ...	D.T.D. 748	8·0- 9·0	13·0-14·5	3- 5	7·5- 9·5	21·5-23·5	5·5-6·0	4·5-5·0
	5·5		0·7		1·8	TZ6 Heat-treated*	D.T.D. 000 (Draft M40)	9·0-11·0	17·0-19·5	5-15	7·0- 9·0	21·0-24·0	4·7-5·2	4·5-5·0
CREEP-RESISTANT ALLOYS														
	2·2		0·6	2·7		ZRE1 As cast and annealed—	D.T.D. 708	5·0- 6·0	9·0-11·0	3- 6	5·0- 7·0	18·0-22·0	4·3-4·7	3·3-3·7
	2·2		0·7		3·0	ZT1 Heat-treated	D.T.D. 5005	5·0- 6·0	12·0-14·0	5-10	5·0- 6·0	20·0-21·0	4·3-4·7	4·3-4·7
WROUGHT ALLOYS														
STANDARD ALLOYS														
		1·5				AM503 Plate, sheet and strip ...	D.T.D. 118a B.S. 1353		13·0-18·0	5-14	N.D.	—	3·7-4·2	—
		1·5				AM503 Extruded bars and sections	D.T.D. 142a B.S. 1355	8·0-13·0	15·0-20·0	4-10	6·5- 8·5	20·0-23·0	4·5-5·2	2·7-3·2
		1·5				AM503 Extruded tube	D.T.D. 737 B.S. 1357	9·0-11·0	15·0-17·0	4- 6	N.D.	—	—	—
3·0	1·0	0·3				AZ31 (high purity) Plate, sheet and strip Half hard ...	D.T.D. 742	10·0	16·0	8	N.D.	—	N.D.	—
3·0	1·0	0·3				AZ31 (high purity) Soft annealed ...	D.T.D. 732	—	14·0 min. -17·0 max.	12	N.D.	—	N.D.	—
6·0	1·0	0·3				AZM Extruded bars and sections < 3 in.	D.T.D. 259a B.S. 1354	11·0-14·0	17·0-22·0	10-18	8·0-11·0	24·0-27·0	8·0-8·7	5·7-6·2
6·0	1·0	0·3				AZM Extruded bars and sections > 3 in.	D.T.D. 749 B.S. 1354	9·0-12·0	14·0-19·0	8-16	7·0-10·0	22·0-26·0	N.D.	N.D.
6·0	1·0	0·3				AZM Extruded tube	D.T.D. 348a B.S. 1356	10·0-12·0	17·0-20·0	8-12	8·0-11·0	—	—	—
6·0	1·0	0·3				AZM Forgings ...	D.T.D. 88c B.S. 1351	10·0-13·0	18·0-20·0	8-14	8·0-10·0	22·0-26·0	7·5-8·2	5·2-5·7
ZIRCONIUM CONTAINING ALLOYS														
						ZW3 Sheet ≥ 18 S.W.G....	D.T.D. 626a	11·0-14·0	17·0-20·0	8-18	9·0-10·5	—	N.D.	—
						ZW3 Sheet < 18 S.W.G....	D.T.D. 626a	10·0-12·0	16·0-18·0		N.D.	—	N.D.	—
	3·0		0·7			ZW3 Solid extrusions > 0·375 in. and up to 4 in.	D.T.D. 622a	14·0-17·0	20·0-23·0	10-25	12·0-15·0	25·0-30·0	7·7-8·7	5·5-6·0
	3·0		0·7			ZW3 Solid extrusions ≤ 0·375 in.	D.T.D. 622a	12·0-15·0	18·0-21·0	10-15	N.D.	—	—	—
						ZW3 Press forgings	D.T.D. 619	13·0-15·0	19·0-22·0	8-14	10·0-13·0	24·0-28·0	N.D.	N.D.
						ZW3 Impact forgings	D.T.D. 729	11·0-14·0	17·0-20·0	8-12	9·0-12·0	24·0-26·0	N.D.	N.D.
						ZW1 Sheet ≥ 18 S.W.G....	D.T.D. 5001	10·0-12·0	16·0-18·0	8-18	N.D.	—	N.D.	—
						ZW1 Sheet < 18 S.W.G....	D.T.D. 5001	9·0-11·0	15·0-17·0	—	N.D.	—	N.D.	—
	1·3		0·7			ZW1 Solid extrusions > 0·375 in. and up to 2 in.	D.T.D. 5011	11·0-14·0	17·0-20·0	10-20	10-13	19-24	7·3-8·0	4·0-4·7
	1·3		0·7			ZW1 Solid extrusions ≤ 0·375 in.	D.T.D. 5011	10·0-12·0	16·0-18·0	10-15	N.D.	—	—	—
	1·3		0·7			ZW1 Extruded tube ...	D.T.D. 5021	11·0-14·0	16·0-20·0	4-15	N.D.	—	—	—
	5·5		0·7			ZW6 Extrusions: as extruded	D.T.D. 5031	13·0	19·0	10	N.D.	N.D.	N.D.	N.D.
	5·5		0·7			ZW6 Extruded and heat-treated	D.T.D. 5041	14·0	20·0	8	N.D.	N.D.	N.D.	N.D.
ZIRCONIUM-THORIUM CONTAINING CREEP-RESISTANT ALLOY														
	1·0		0·7		2·7	ZTX Plate, sheet and strip	—	8·0-11·0	15·0-17·0	12-20	N.D.	—	—	—
	1·0		0·7		2·7	ZTX Extruded bars and sections	—	10·0	15·0	20-30	N.D.	—	—	—
	1·0		0·7		2·7	ZTX Forgings	—	9·0	15·0	10-20	N.D.	—	—	—

Note: British Standards above with the prefix "L" refer to aircraft specifications. *TZ6 is also creep resistant up to 200 deg. C.

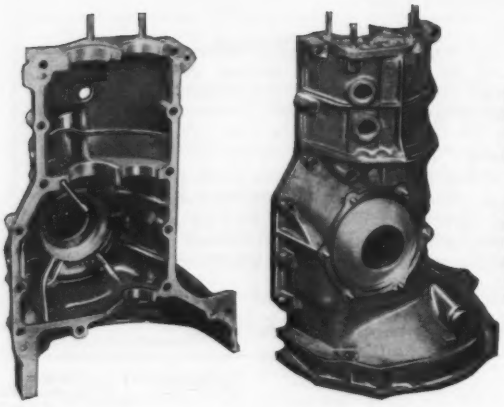


Fig. 9. *Left.* Pressure die - cast magnesium rear axle and transmission housing of the Volkswagen car.

Fig. 10. *Right.* Large magnesium castings for a mobile military electronic unit. Lower casting is 7 × 8 × 3 ft., weighs 1,500 lb. Upper unit weighs 550 lb.

Magnesium alloys are comparable with the aluminium alloys, and to some extent with certain of the heat-treated steels. Recent research work has indicated that the notch sensitivity of magnesium alloys in impact is no greater than that of mild steel. However, as in fatigue, it is essential to minimise the stress-raising influences when designing magnesium components subject to impact loading. Experience with well-designed magnesium components has done much to discount the importance of the low impact value obtained on laboratory specimens. For instance, magnesium aircraft wheels have proved to be among the most reliable metallic components ever produced. Despite the arduous conditions of shock loading incidental to improvised airfields in many parts of the world, the number of failures has been infinitesimal.

Effect of Temperature—The influence of elevated temperatures on the 0·1 per cent proof stress (offset) properties of a number of common magnesium casting alloys is illustrated in Fig. 12. In the first place, it should be noted that the zirconium and rare-earth-containing alloy ZRE1 and the zirconium-thorium-containing alloys ZT1 and MTZ, while being weaker at room temperature than some of the other alloys, show enhanced retention of strength between 200-250 deg. C. for ZRE1 and 250-350 deg. C. for ZT1 and MTZ. The magnesium-silver-rare earth-containing alloy MSR-B has the highest proof values over 280 deg. C. The other alloys, however, whilst retaining considerable strength up to 100 deg. C., weaken steadily with increasing temperature, so that their use at temperatures above 150 deg. C. is not recommended. They can, however, be used with confidence at low temperatures (−70 deg. C.) and at temperatures up to 100 deg. C.

Creep at Elevated Temperatures—If service conditions involve the continuous exposure of stressed parts to elevated temperatures, creep resistance will most probably be the governing property. Here casting alloys ZT1, ZRE1 and MCZ are outstanding, and TZ6 is suitable in many cases. The creep resistance of the wrought alloy ZTX is illustrated in Fig. 13.

Uniformity of Properties—The figures for mechanical properties quoted in Table 5 have been obtained, in respect of the casting alloys, from separately cast test bars. It may not be possible to realise these values in all parts of a complicated casting. On the other hand, where required, values approaching test bar figures can generally be obtained in critical portions of castings by suitable design and casting technique. This is specially true of the magnesium-zirconium casting alloys, the properties of which are very uniform.

Product Design—For correct choice for a given part, the dimensional and qualitative limitations of the various available processes of fabrication and assembly must be taken into account. Several modern processes of fabrication which cannot be used for ferrous alloys can readily

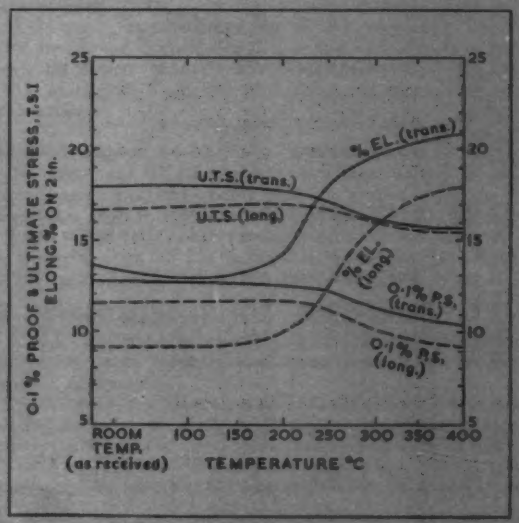


Fig. 11. Effect on properties of ZW3 sheet of preheating for 30 min. for hot forming.

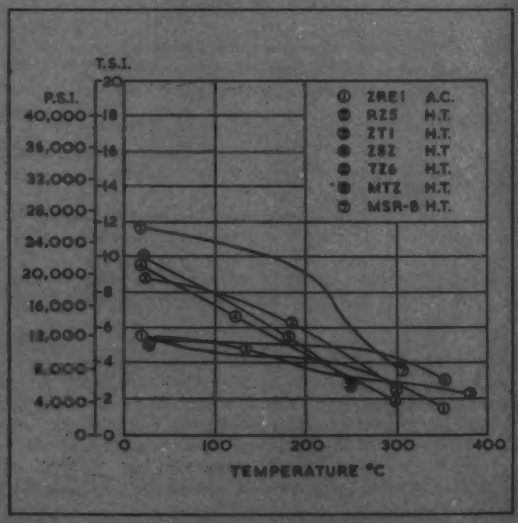


Fig. 12. Effect of temperature on the 0·1 per cent P.S. (offset) of various magnesium cast alloys.

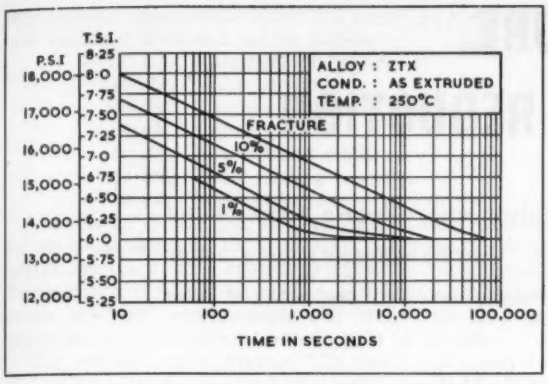


Fig. 13. Stress/time relationship for specified total strains: extruded ZTX at 250 deg. C.

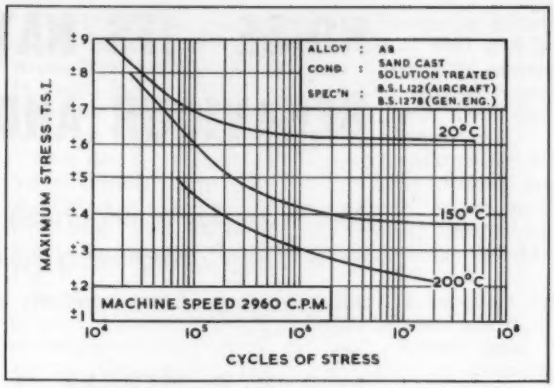


Fig. 15. Wohler fatigue tests on solution-treated A8 alloy.

be used for magnesium in common with aluminium and other non-ferrous metals.

Also, a magnesium part may often be made by one or more processes, since many of the cast and wrought forms are readily weldable with but little fall in strength.

Current and Future Uses

Through its early years of development, structural magnesium was best known for its applications in the aircraft field; large tonnages are used in wheels, engine and airframe stressed parts and accessories. In more recent years the aspects of unlimited supply and a more favourable price position (in some forms it has now approached and in many instances reached a price comparable to other metals on an equal volume basis) has encouraged many other industries to use magnesium alloys.

In the materials-handling field light weight and durability have led to its adoption for sack trucks, dockboards, gravity conveyors and foundry equipment. The portable tool industry is using magnesium for drill casings, portable chain saws (Fig. 4), road hammer parts and manually-handled equipment of this nature.

Industrial machinery of many types takes advantage of light weight, particularly where lower inertia results in increased speed of operation, e.g., textile and printing machinery parts and accessories.

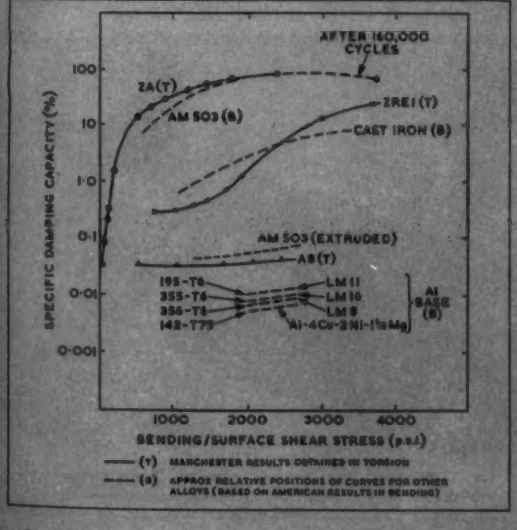


Fig. 14. Comparison of approximate damping capacity data for some magnesium alloys with cast iron and aluminium.

In the nuclear energy field, Magnox A12, a magnesium alloy containing approximately 1 per cent of aluminium and a small amount of beryllium, is used for fuel elements in gas-cooled reactors like Calder Hall. The reasons for its adoption are low neutron absorption, resistance to CO_2 at temperatures up to 480 deg. C. and because it does not alloy with uranium.

The transportation field offers one of the largest potential uses for magnesium. Already in the U.S.A. it is used in wrought form for truck bodies, trailers and motor car components and also as pressure die-castings for fuel pumps, etc. In the U.K. one of the largest uses was the gear case of the Ferguson tractor, of which some 600,000 have been produced. Crankcases, sumps and gear casings of heavy vehicles have long been cast in magnesium. A notable technical experiment was the "G" type E.R.A. motor car frame which combined a weight of under 100 lb. with a stiffness factor of 3,300 lb./in. per degree of distortion.

The extensive use of magnesium pressure die-castings in the Volkswagen engine (Fig. 9) provides a pointer to future development. It is probably the largest single use of magnesium in the world—over 11,000 tons a year. The crankcase, rear axle and transmission housings are die-cast and weigh about 36 lb., replacing what would be approximately 1 cwt. of cast iron.

Weight distribution, steering and directional stability are important factors in the design of rear-engined cars. Weight saving was not, however, the sole reason determining the use of magnesium in the V.W. engine. The very high rate of output of the die-casting process, the reduction in machining time to a quarter that of cast iron and two-thirds that of aluminium, were important considerations. Twenty transmission housings are produced per hour per machine. The die life for the crankcase is stated to be 120,000 shots. Magnesium's low specific heat and resistance to alloying with steel results in appreciably increased die life over aluminium.

These examples have led to considerable interest by the U.K. motor industry, and some leading manufacturers have designs employing magnesium under consideration.

Limited pressure die-casting facilities and the lack of machines large enough to produce castings of up to 35 lb. have prevented earlier entry into this field in the U.K., but the situation is now changing.

REFERENCES

1. Ball, C. J. P. "History of Magnesium", *Journal of the Institute of Metals*, **84**, Part 11, 1955-56.
2. Wilkinson, R. G. "Hot Forming of Magnesium Alloys", *Journal of the Institute of Metals*, **84**, Part 7, 1955-56.
3. Fielding, J. "Rubber Pressing", *Journal of the Institute of Metals*, **84**, Part 6, 1955-56.
4. Emley, E. F. "Metallurgical Background to Magnesium Alloy Welding", *British Welding Journal*, **4**, No. 7, July 1957.
5. Higgins, W. F. "Modern Concepts in the Protection of Magnesium-base Alloys", *Light Metals*, August 1955.

NOISE – ITS NATURE, BEHAVIOUR AND REDUCTION

This is the first of two articles dealing with effective noise control in the design of engineering products. Factors necessary for a better understanding of the problems commonly involved are outlined here

by D. M. A. MERCER, M.A., B.Sc.*

NOISE is a problem of which people in this country are becoming increasingly conscious, and there are many situations in industry where noise reduction measures are urgently desired. Many unsuccessful attempts at silencing are based on complete misconceptions of the nature of sound and its transmission, but anyone with a thorough understanding of the problem is much more likely to use his knowledge correctly and to apply a silencing technique which is likely to be successful.

The basic definition of noise is that it is "sound undesired by the recipient". This definition immediately suggests that there is a human problem (the words "undesired"), and in fact nearly all noise problems are concerned with human response in some way. However, in this article "noise" will be used to describe a physical sound (rather than human reaction to it) when sound of a rather special type is discussed, i.e., the entirely random sound produced by many types of noise generators, in contrast to, say, musical sounds. "Random noise" is, in fact, a term often used for this; it will be discussed in more detail later.

SOUND WAVES IN AIR—Sound in air is a wave-motion, consisting of alternate compressions and rarefactions; when these fall on the eardrum, which is sensitive to pressure changes, a sensation of sound is heard. Sound waves can travel down a metal bar in much the same way, or by a bending wave travelling down it; in a complex structure both these, as well as other forms of vibration, may take place.

There is basically no difference between sound and vibration in structures. The human ear perceives sound in the range 20-20,000 cycles per second (c/s) approximately (a cycle being one complete oscillation), although vibration can be perceived at lower frequencies.

An important point to realise about sound waves is that the quantities are so small. People sometimes wonder how, for instance, a massive brick or concrete wall can vibrate so as to produce a sound. The answer is that an amplitude of vibration of only half a millionth of an inch at 1,000 c/s would be needed to generate a sound which would be quite audible above conversation. At this frequency, the ear can detect a sound when the movement of the air molecules carrying the sound wave is much less than the diameter of an atom.

MEASUREMENT OF SOUND— Sound is measured in terms of decibels, and as the use of decibels is so important it is worth studying them in some detail.

The decibel (abbreviated dB.) is defined in terms of a ratio between two powers or two energies. Sound is a form of energy, and thus the decibel has a natural application. If W_1 and W_2 are two powers, the number N of decibels by which W_1 exceeds W_2 is given by

$$N = 10 \log_{10} \frac{W_1}{W_2}$$

If, say, W_1 is one hundred times W_2, N is equal to 20; we say that W_1 is "20 dB. higher" than W_2. A few ratios are:

W_1/W_2	1/100	1/10	1	2	3	10	100
N, dB.	−20	−10	0	3	5	10	20

It is easy to compute other ratios. Since the decibel is a logarithmic quantity, decibels must be *added* when powers are *multiplied*. Thus a ratio of 200 may be taken as 2 × 100, or in decibels 3 + 20; i.e., a ratio of 200:1 corresponds to 23 dB. Other ratios can easily be found.

To use the decibel for acoustic quantities, it is necessary to have a standard reference (i.e., a value for 0 dB.). For sound waves in air, this is taken to be an intensity of 10^{-16} watts transported across 1 cm.^{2} in 1 sec. This is equivalent (under specified conditions) to a sound wave with an r.m.s. pressure variation of 0·0002 dyne/cm.^{2}. Strictly, therefore, one should not say, e.g., "a noise level of 60 dB.", but "60 dB. re 0·0002 dyne/cm.^{2}". In practice, however, it is usual to say "60 dB. re the usual zero", or else omit it altogether when there will be no ambiguity. (It will be omitted in this article). However, in the case of a precise statement, e.g., a graph of noise level, the reference value should always be given.

The term "sound level" or "noise level" is used as an indication of the intensity of the sound. Some typical

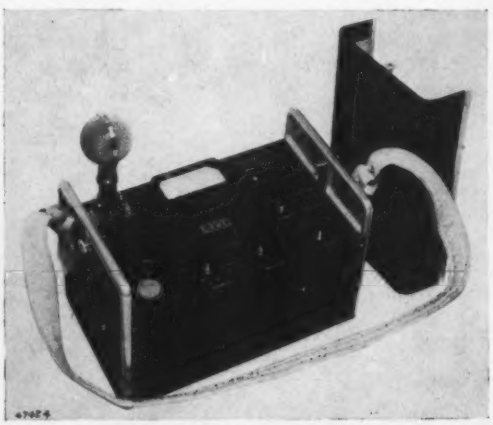


Fig. 1. A sound level meter (made by Dawe Instruments Ltd.), the basic instrument for measuring noise.

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approximate noise levels, which will simply give an idea of the quantities discussed, are as follows:

0 dB.	Threshold of hearing
20 dB.	Quiet garden
40 dB.	Average home background
60 dB.	Conversation
80 dB.	Heavy street traffic
100 dB.	Near riveting machine
120 dB.	Near jet engine

The decibel is also useful when dealing with silencing, or the transmission of sound through a structure or device which reduces it. This process is known as "attenuation". For instance, if a machine is in an enclosure, and the level inside is 95 dB., while outside it is 54 dB., the enclosure produces an attenuation of 95 minus 54, or 41 dB.

THE SOUND LEVEL METER—The basic instrument for measuring noise is the sound level meter (see Fig. 1). This is a self-contained instrument consisting of a microphone, amplifier and indicating meter, reading directly in decibels. The sound level at any point may thus be measured directly.

The sound level meter is a simple and convenient instrument to use, but it is by no means easy to obtain accurate results. Very considerable errors in noise level may be made if the instrument is wrongly positioned. Some of these errors can be avoided by noting the remarks made later on the behaviour of sound in an enclosure, but in general it is most strongly recommended that skilled advice —and, if possible, example—should be obtained before the instrument is used by inexperienced people.

ANALYSIS OF NOISE—The sound-level meter, though useful, is quite limited. Two noises which give the same indication on the meter may sound quite different to the ear, and this is because the components of the sound are not the same at different frequencies. To understand this, it is necessary to consider what is called the "spectrum".

A sound wave in air in which the pressure variation is a true sine wave is called a pure tone, since it cannot be broken down into further constituents. It is shown in Fig. 4a, and may be represented as its spectrum in Fig. 4b. This shows a graph of intensity against frequency, and the tone is represented as a line situated at its frequency and of height indicating its intensity.

Now it may be shown that random noise can be considered as the superposition of a very large number of sine waves of all frequencies. The sum of these will produce the entirely random pattern as shown in Fig. 5a, and its spectrum is a very large number of lines, one for each sine-wave. This is shown at the left-hand side of Fig. 5b, but in practice it is usual simply to draw a line going through the ends of all the vertical lines, as in the remainder of the figure. This line represents the spectrum of the noise.

Clearly, different kinds of spectra characterise different sounds. Consider the two shown in Fig. 6. That at A has strong high-frequency components: it would be expected to sound like a hiss, as steam escaping through a small valve, for instance. That in B would sound more like a "roar" or "rumble" e.g., the sound of a heavy lorry.

Note that it is possible also to have a spectrum which is a combination of Figs. 4 and 5 for a noise producer such as a gearbox. This will produce periodic sounds at the frequencies with which the teeth engage, together with general background noise, and gives a spectrum such as in Fig. 7.

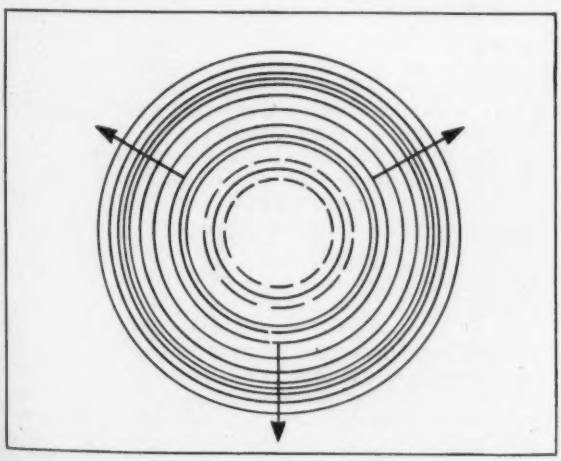
INSTRUMENTS FOR NOISE ANALYSIS—An important part of noise investigations is the analysis of such spectra, representing different kinds of noise. Several types of analyser are available, and it is important to understand their different uses. They all contain circuits known as filter circuits, since they filter only the noise contained in a narrow range of frequencies from the noise at all other frequencies. The spectrum may be considered to be divided up by the vertical lines shown in Fig. 8, the short horizontal lines at each point represent the average values in each band, the analyser being tuned to one at a time. These values are indicated on the dial of the analyser. (For no ambiguity, they should be quoted as "sound level in band" and the type of analyser specified.)

There are two types of analysers, narrow-band and broad-band. Both cover the whole audible range. The first are quite sharply tuned; the bandwidth may be only a few cycles per second, or some small fraction, e.g., two per cent of the frequency to which they are tuned. Such an analyser, tuned to 500 c/s, would pass all components of the sound between 495 and 505 c/s, indicating the sound level in this range only, and rejecting all other components.

Such an analyser is most valuable for detecting pure tones, or picking out the peaks of spectra such as those in Fig. 7. It must be emphasised, however, that it is almost impossible to use it for general noise work, for which the type of analyser to be described next is needed.

Broad-band analysers divide the spectrum into, usually, bands of either one octave or one-third of an octave wide. Typical bands would be 600-1,200 c/s in the first case, and 720-900 c/s in the second. They are most valuable for general noise work. Often the octave-band analyser is preferred for field work and results taken on the spot, while the third-octave band analyser is preferred for detailed examination in the laboratory; but there is no hard and fast rule.

Two points may be made here. One is that if the spectrum is steeply sloping (as at A in Fig. 8), the average value indicated in the band may not be a very accurate indication of the varying sound level in the band. The other is



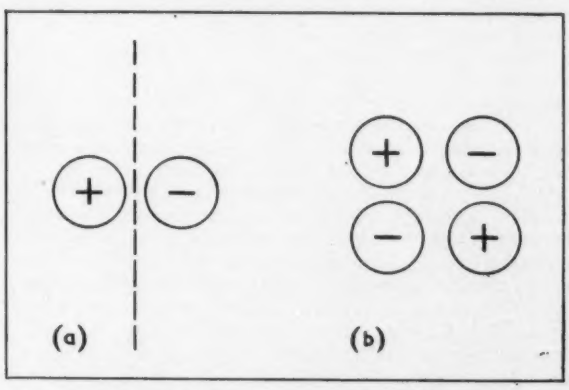


Fig. 3. *Above.* (a) dipole source; (b) quadrupole source.

Fig. 2. *Left.* The simple source—the most fundamental noise source.

that, even apart from this, the filter tuned to band A may not in fact be able to reject sufficiently the very high-intensity levels around B, and the reading for band A would be inaccurate. Whenever a spectrum extends over 40 dB. or more, this point should be watched; auxiliary filters may be used, or some other precautions taken.

FURTHER TYPES OF NOISE MEASUREMENT—There are, of course, many other ways of making noise measurements. A tape recorder may be used, in conjunction with a microphone, to record a short sample of noise, which can then be played over many times and analysed at leisure. A very useful instrument is the high-speed level recorder: this is virtually a recording millivoltmeter, with a decibel scale and a very fast response. It can be connected to the output of an analyser and used to give a graphic record of the sound level in the different bands; or it may be used to record the level of a fluctuating noise.

In all noise analysis, great care must be taken to maintain accuracy. Battery-driven instruments can vary in sensitivity with time or battery voltage: the performance of electronic instruments generally needs periodic checking. Calibrating instruments are generally available and should be used.

IMPULSIVE NOISES—So far, discussion has been confined to sounds which are more or less steady with time. Certain types of noise, however, such as the crash of a drop hammer, are known as impulsive. They may have a time-pattern as shown in Fig. 9. Recently, instruments have become available for measuring these and for analysing their spectra. However, it is possible to obtain some information by using a level recorder or a cathode-ray oscilloscope.

CORRELATION TECHNIQUES—The author is currently working on a new means of sound analysis, known as correlation. There is no space to describe it here, except to say that it uses the actual waveform of the random noise (Fig. 5). It is possible to detect an extremely weak sine wave buried in noise, to identify one out of several nearby noise producers, and in general to analyse problems which cannot be solved by conventional noise analysis. It is a method which appears to hold a lot of promise.[1]

The Production of Sound

THEORETICAL SOUND SOURCES—Having considered different types of noise in general terms, consideration should now be given to the types of motion which give rise to sound, i.e., to sound sources. It is worth while to deal with them in some detail, for a fundamental understanding of the subject; even though in general noise control work the ideas may be simplified.

The most fundamental type of source is the so-called simple source, a sphere regularly pulsating in diameter (see Fig. 2). This generates spherically symmetrical waves, alternate compressions and rarefactions, which travel outwards with the speed of sound.

No source of this exact form exists, but it may be shown that any practical source does in fact behave like a simple source—and hence radiates non-directionally—if it is much smaller than the wavelength of the sound it emits. Thus a back-enclosed loudspeaker at low frequencies, or a small petrol engine, may be considered as simple sources.

A dipole source is formed when, instead of periodic changes in volume (as in the simple source), there are periodic changes in momentum. A loudspeaker in an open baffle or a large vibrating panel with free space on its two sides exemplify this type of source. It may in fact be represented by two simple sources, close together and out of phase (Fig. 3a), the + and − signs denoting the phase.

It will be seen that the dipole is directional; for instance, in the figure the two sources cancel out at any point on the dotted line. There will thus be no sound in this plane corresponding to the plane of the baffle or of the panel mentioned earlier.

When considering the sound radiation from a mass of turbulent gas, as in the jet engine, or a high-pressure pipe outlet, it is not possible to consider that the noise is produced in either of these ways, as there are no changes in volume (within the mass of gas) to give simple sources, and nothing to withstand the momentum fluctuations required by dipoles. It has recently been shown that the characteristic sound radiators are "quadrupoles", which may be considered as two superimposed dipoles in opposite phase (see Fig. 3b).

SOUND SOURCES IN PRACTICE—Practical sound sources may be considered as combinations of these. The exhaust of a pneumatic drill, or the average noisy machine, would correspond to simple sources. Vibration due to unbalanced machinery would be probably of a dipole character, the machine moving bodily to and fro. Gas discharges give quadrupole noise; if combustion is present, simple sources will be there as well. Fluid discharges through pipes or ducts will cause the duct to distort in a complex manner under the forces in the turbulent flow, radiating mainly as an array of simple sources.

As has been said, however, in practical cases, in which sounds are generated in enclosures where there are multiple reflections, to a first approximation sources should be considered to behave as simple sources. In particular, a warning should be given about assumptions of directional sound radiation. Too many people believe that sound travels in the same way as the beam from a flashlamp! Phrases like ". . . the sound travels out sideways, reflects off the panel in the wall . . ." are heard far too often from inexperienced people. It is strongly recommended that, until experience is gained, all sources should be considered non-directional. In noise control work this assumption, and the one about the simple source, result in an over-estimation of the effect, and hence provide a factor of safety for any silencing treatment.

POWER OF SOUND SOURCES—Sound is a form of energy, and output of sound sources can be calculated in terms of power. The unit is the watt, but this corresponds to the amount of power radiated from, say, a large aircraft engine, and industrial sound sources have powers usually in the milliwatt region.

A useful concept is the power level (abbreviated PWL) of a sound source, which is defined as the power measured in decibels, with a reference value of 10^{-13} watts. Thus, for a source of power W watts,

$$\text{PWL} = 10 \log_{10} (W/10^{-13}).$$

While this reference may seem arbitrary, it has the following property: the PWL of a source is numerically equal to the sound level on a spherical surface of 1 sq. ft. area (i.e., approx. 3¼ in. radius) surrounding the source, or surrounding an equivalent non-directional point source.

Suppose a compressor, with a PWL of 90 dB., were placed at one end of a long building open at the other end. If all the sound energy is assumed to be travelling out of the open end of the building, and this end had an area of 200 sq. ft. it may be reasoned as follows:

A PWL of 90 dB. means a sound level of 90 dB. spread over 1 sq. ft.; as the sound is now spread over 200 sq. ft., the level at any point will be diminished in the ratio 1/200. Thus the sound level in dB. will be given by

$$90 - 10 \log_{10} 200 = 90 - 23,$$
or 67 dB

Such calculations may be used to find the sound level due to the compressor in other environments, as will be dealt with in the second part of this article. Often, of course, such a calculation will be made the other way round, that is, a measurement of sound level at one point may be used to calculate the PWL of a source.

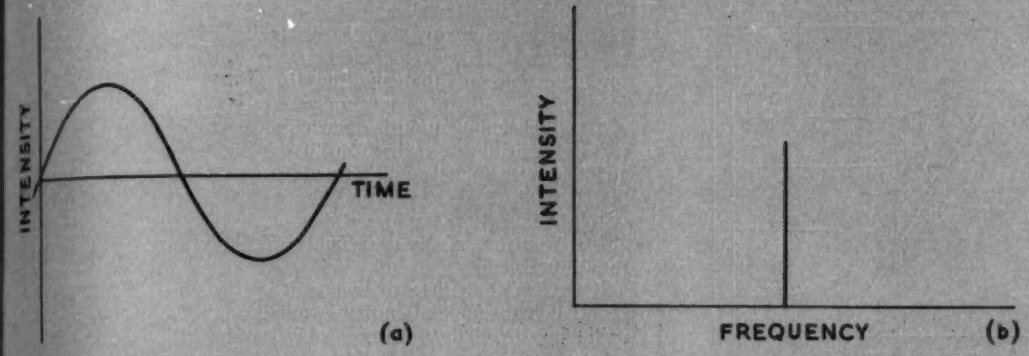


Fig. 4. A sine wave or pure tone: (a) time-pattern; (b) spectrum.

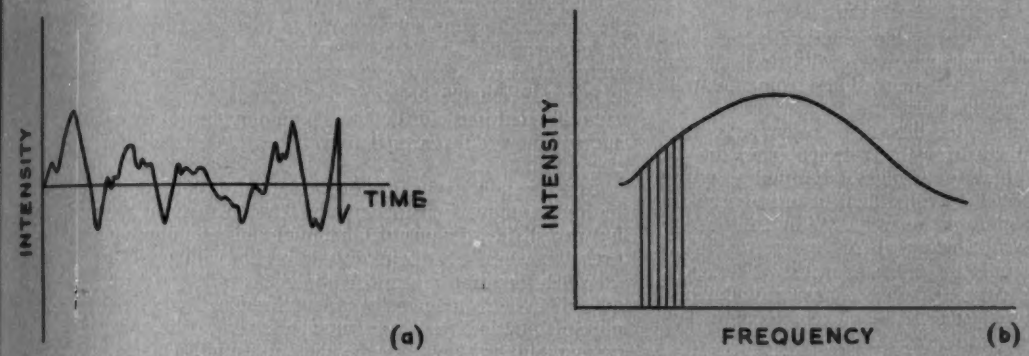


Fig. 5. Random noise: (a) time-pattern; (b) spectrum.

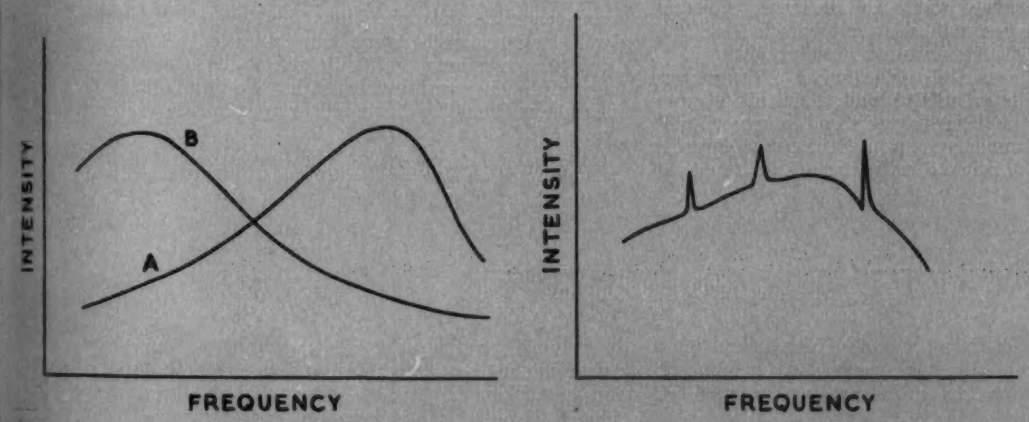


Fig. 6. *Far left.* Different types of spectra, with high frequencies predominating at A and low frequencies at B.

Fig. 7. Spectrum of noise containing pure tones in a random noise background.

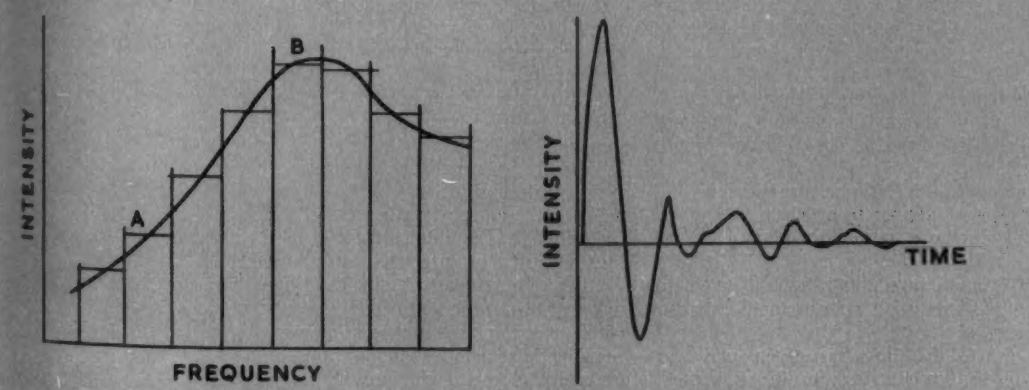


Fig. 8. *Far left.* Division of a spectrum by a analyser.

Fig. 9. Time-pattern of impulsive noise.

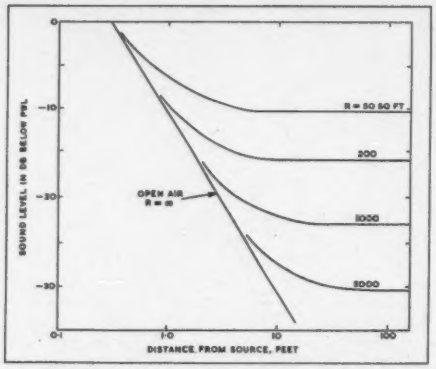


Fig. 10. Sound level of a source in an enclosure.

Behaviour of Sound in Enclosures

If there is a sound source in any enclosed space, i.e., a room or factory building, sound waves will travel out from the source, and be reflected many times from the walls. Two main regions may be considered:

1. Near to the source the direct sound waves from the source will predominate over the reflected ones, the distance over which they predominate depending on the strength of the reflected waves, which in turn depends on the degree of absorption at the walls. Within this region, then, the sound waves behave as if the source was in free space, without any reflecting surfaces nearby. The sound level will fall off at a rate of 6 dB. for each doubling of the distance (a consequence of the inverse square law). This region is known as the free field.

2. Very far from the source, the multi-reflected sound waves, from walls, ceiling, etc., will predominate over the direct sound. The sound waves will be travelling in all directions, and over a certain distance the sound field will be quite uniform. This is known as the diffuse field.

It is possible to present this behaviour in a diagram, as in Fig. 10. It is quite essential to understand this diagram if a true picture of the behaviour of sound in an enclosure is desired. R is a parameter known as the room constant, defined as $S\alpha/(1-\alpha)$, where S is the area of the room and α the absorption coefficient of the walls. This quantity is the fraction of energy absorbed when a sound wave strikes the surface: it is given in tables for most surfaces. The ordinate represents the sound level compared to the PWL of the source, a further advantage of using PWL.

The line sloping at 6 dB./octave represents the behaviour of sound in the open air. Considering the curve for R = 1,000 (approximately an average factory room 10 ft. × 25 ft. × 40 ft.), it is seen that the free-field region extends out to about 2 ft. from the source. Further than about 10 ft. from the source, the sound level is uniform; this is the diffuse field.

It is clear that these regions can be used in two ways. If a detailed examination of the sound output of a source, including directivity measurements, is wanted, it is necessary to keep in the free-field region. If, however, an average value of the sound output is wanted, the microphone must be placed in the diffuse field region.

There are some points which call for comment. If, say, the source in the previous case was 4 ft. across, there would be no near-field region. Measurements very near to a source (at, say, a distance comparable to its length) are not in general valuable because of different sound radiation from different parts of it. The diagram applies to a "point" source: in certain cases it may have to be treated with discretion.

Another point concerns the presence of pure tones in the noise output from the source. These can form "standing waves", i.e., regions of maximum and minimum sound level. The effect is easily noticed in a room with a television set which has the frequent high-pitched whistle: considerable differences in intensity are noticeable if the head is moved a few inches. If measurements have to be taken in such conditions, they must be made at a number of points, and averaged.

Standing waves do not normally arise with random noise, except near the walls or ceiling. The sound level rises as a wall is approached nearer than about a half-wavelength, rising to a maximum of 6 dB. above the general level. Thus in making measurements in the diffuse field the microphone should be kept well away from the walls.

1. Mercer, D. M. A. "Application of Correlation Techniques in Noise Analysis", *Annals of Occupational Hygiene*, 1, 81-89 (December, 1958)

HIGH-TEMPERATURE CERAMIC HONEYCOMB

EXTREMELY thin-walled ceramics formed into lightweight honeycomb structures capable of operating at high temperatures have been introduced by Corning Glass Works in the U.S.A.

These materials, made by the new Cercor process, can withstand temperatures up to 1,000 deg. C. with virtually no thermal expansion, and can operate continuously at 700 deg. C. At these temperatures they are resistant to oxidation and corrosion.

A unique characteristic of these materials is their extremely low coefficient of thermal expansion—1×10^{-7} per deg. C. (from 0 to 300 deg. C.). They can withstand extreme thermal shock.

It is said to be possible to build Cercor structures having a wide range of shapes and properties; the base material can be any of a large number of ceramic compositions.

Pyroceram, a high-strength crystalline material invented by Corning, is used as one of the base materials for available Cercor pieces.

Discs, 20 in. dia. and 3¼ in. thick, have been made by the new process. A protective rim for the disc is formed by a tough coating of special material with matching expansion and equally high resistance to temperatures. This rim can be applied to all sizes of pieces to protect the thin-edged walls against excessive outside stresses. It can also be used as a convenient mounting support.

Available Cercor pieces have a compressive strength, parallel to the channels, of 2,000 p.s.i. Surface area of the 20-hole-per-inch corrugated structures is 1,500 sq. ft./ft.^{3} of material.

Of the total face area, 75 to 80 per cent is open space. Hole sizes of Cercor pieces are approximately 0·095 in. long and 0·045 in. high. It is believed that the cellular holes can be formed into a variety of shapes with a wide range of dimensions.

The material has a density of about 30 lb./ft.^{3} and a specific heat (room temperature) of 0·20. Average wall thickness of the corrugated structure is 0·005 in.

Among the range of uses to which the new materials may be put are air preheaters and after-coolers, as burner plates or covers, column packing material, in gaseous heat exchangers, as catalyst supports and as structural materials for use at elevated temperatures.

NEW IDEAS IN DESIGN

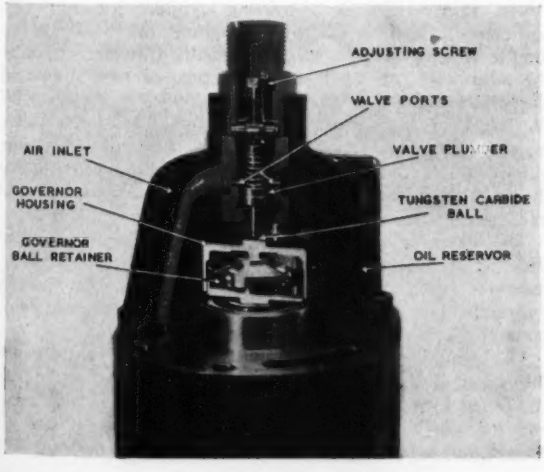
Outstanding products in current manufacture

Ingenious Governor Mechanism for an Air-driven Pump

THE conventional type of governor used in air-operated motors employs balance weights exposed to the incoming air-stream which can cause centrifugal water separation and consequent corrosion. The novel form of governor system employed in the Blagdon-Durham AP.2, a portable general-purpose sump pump, has been compactly designed as an enclosed unit to eliminate this trouble. As the governor weights are out of the incoming air-stream this tendency is avoided. A further precaution is taken by providing a renewable air filter which can be ejected by pressing out the adjusting screw assembly by hand when the hose connector nipple is removed.

Speed adjustment of the vane-type rotor can be made by removing the air-inlet hose and turning an adjusting screw within the bore of the inlet adaptor. This screw controls the pre-loading of a compression spring. The lower end of the spring is urged against a sliding plunger which acts as a slide valve, the edge of the plunger serving to occlude four ports drilled radially in the walls of the cylinder. At the point where the ports emerge, the cylinder has a wide groove which serves as an annular space for the air to pass through on its way to the rotor. A spigot extension of the valve plunger, of considerably smaller diameter, passes through the end of the cylinder and is provided with a tungsten carbide ball end which bears against the upper half of the centrifugal governor housing, which is provided at this point with a hardened tool steel pad. This arrangement eliminates the need for lubrication at this point.

The governor consists of a radially-slotted bronze retainer carrying four balls which are free to slide within the slots. The governor housing is in two halves, the upper half being a slide fit on the lower. Each half is fitted with a hardened steel ring, the chamfered face of which bears against the balls. It will be seen that centrifugal force acting on the balls will cause them to move outwards in the slots, thus forcing apart the chamfered rings and halves of the housing. This will occur until the spring-loading of the upper half of the housing effectively prevents further movement.



Lubrication of the air motor is effected by the admission of air to a large oil reservoir, fitted with an external filler plug, via two ports from the air inlet, these ports communicating transversely with a cylindrical felt plug, the compression of which is controlled by an external socket head screw.

When air is supplied to the motor the oil reservoir gradually becomes pressurised and lubrication is provided. Residual pressure in the reservoir after running causes an oil bleed to the rotor which serves to lubricate the pump when it is next used. The possibility of condensation is further guarded against by the fact that the rotor housing is made of stainless iron.

Other unusual features of the AP.2 include a vertical air exhaust port and an arrangement of lip seals which effectively prevents air under pressure reaching the pump from the motor. Particular attention to detail design has reduced noise to a minimum. The open-sided bronze impeller has been designed for the pumping of liquids with solid matter in suspension. Output at 80 p.s.i. is 180 gal./min. at 10 ft. head and up to 50 gal./min. at 70 ft. head with air consumption of 70–80 cu. ft./min.

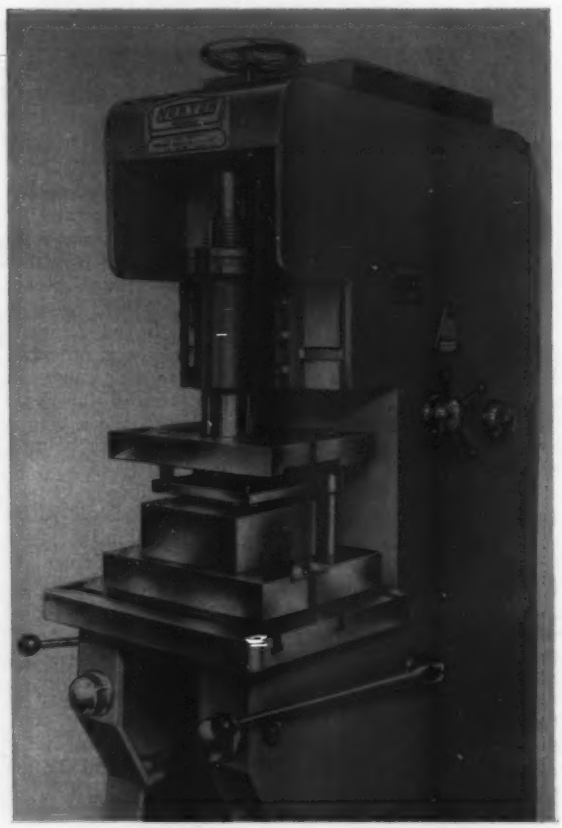
When lesser duties are to be performed, adjustment of the governor limits the take-off from low-output compressors or multi-tool systems. The overall height of the AP.2 is 18 in., the maximum diameter 11 in. and the net weight 56 lb. The air inlet connection is ¾-in. B.S.P., air exhaust connection 1-in. B.S.P.

High-speed Hydraulic Press of Wide Utility

UNTIL now the fastest tool for mass production has been the crank press. An immense number of sheet-metal components are produced annually on such presses. As a general rule, the output of small components made from steel strip comes from presses operating at around 120 strokes per minute.

A new hydraulic press by the Norton Tool Co. greatly exceeds this figure. Although of only 7½-ton capacity, work can be carried out on it that normally requires a 25-ton crank press and at a speed of 380 components per minute. This is achieved by putting an amount of 'shear' on the die (to spread the load during blanking) that would not be possible with a crank press because the peak pressure would only be reached at the bottom of the stroke. In a hydraulic press, however, blanking pressure is uniform throughout the length of the stroke.

For smaller components still greater speeds of up to 600 strokes per minute are possible, while for operations such as riveting or second-operation shaving, high-speed reciprocation of the ram at 1,500 strokes per minute is possible. Not only is the number of strokes per minute infinitely variable, but the Norton press has great flexibility in that six pressing speeds from 34-326 in./min. are possible, with a range of six fast approach speeds. Infinitely adjustable pressure, from one-tenth of maximum pressure to maximum, is possible (with pressure-sensitive return if required), while linear return makes the press particularly suitable for certain types of moulding and forming. Dead stops are rendered unnecessary.



A single control wheel provides the following types of cycling: semi-automatic, full-automatic, full-automatic with infinitely variable dwell at bottom of stroke, full-automatic with repeat strokes at bottom of stroke and full hand pressure sensitive control providing positive inching for tool setting.

The unique performance characteristics of the press are the result of a combination of a novel hydraulic system and an all-steel welded frame. The bed, which is removable, is supplied in two types. The first of these, measuring 20 in. × 14 in., has three standard T-slots and a 6-in.-square through hole with no reducing adaptor. The second type is of the same area and is also T-slotted, but has a centre nesting adaptor which reduces a through hole of 6 in. dia. to 2 in. dia. The press can be used without a bed in cases where it is necessary to accommodate unusual set-ups and long tooling in the U-shaped front.

It can be supplied on a stand (as shown) or can be bench mounted. The fact that provision is made for external hydraulic control, however, suggests that a number of such presses could be mounted on a common base and synchronised so as to provide a new type of transfer press of great versatility. The range of press-feeding accessories, available as optional extras lends support to this idea as a possible future development.

The hydraulic pump, which carries a combined flywheel and heavy-duty multiple V-velt pulley, is driven by a 7½-h.p. heavy-duty motor. It is of the multi-cylinder type and can sustain full pressure at a continuous rating of 7,000 p.s.i. All valves are of the guided mitre design, ground and lapped to hardened seatings. The main bearings are double row self-aligning spherical rollers and the eccentric bearings are built up directly on a hardened chrome shaft. As the flywheel runs at 1,500 r.p.m. there exists a capacity for energy storage far in excess of that provided by the ordinary crank-press flywheel, using a motor of comparable output. The flywheel carries a fan for cooling the oil as it passes through a unit for this purpose, on the top of the machine. The air for this unit is drawn through the central part of the machine.

The ram, which is a moving cylinder guided by a stationary piston, is guided throughout the whole of its length, the top section being externally threaded to carry the adjustable top dead stop. The type of ram shown in the illustration is an optional extra and is provided with two heavy guide members, but normally the press relies on a vee-way machined in the ram, running on a full-length gib, to prevent rotation. The accuracy and rigidity thus provided enable press tools to be used without the expense of die sets.

The machine requires no external connections other than to the electric supply to the motor, the hydraulic reservoir being at the back of the machine. The various hydraulic units are designed as units, thus providing easy maintenance.

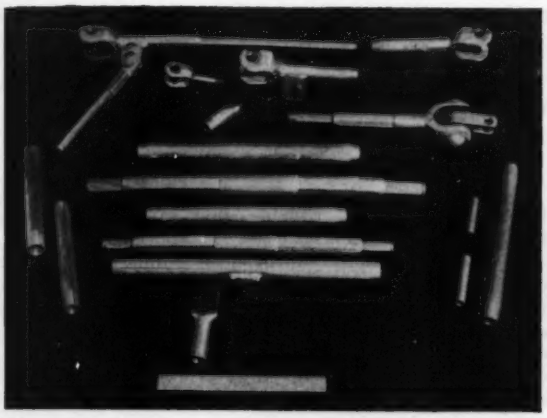
The simplicity of layout and absence of extraneous fittings other than a few control levers and selector knobs, combined with unitised construction for the main hydraulic and mechanical units, has resulted in a machine tool of remarkable versatility and elegance.

Portable Compressor for fitting Aluminium Conductor Accessories

TO facilitate the fitting of their new range of Noralgrip conductor accessories, or for other similar applications, the Northern Aluminium Co. have recently introduced a portable supply of hydraulic power and a press in one unit. Two hydraulic plunger-type pumps are driven by an eccentric shaft and reduction gearing, enclosed in a cast aluminium alloy housing that serves as an oil bath and oil reservoir. Power is supplied by a 2-b.h.p. Villiers two-stroke constant-speed motor mounted on top of the housing. Alternatively an electric motor can be fitted if required.

The pump is capable of generating hydraulic pressure up to a rated capacity of 7,800 lb./sq. in. of ram area, an automatic relief valve operating at this pressure to prevent damage. A single lever controls movement of the ram. Oil-resistant, rubber-covered, double-wire braided high-pressure hose connects the power unit to the ram head.

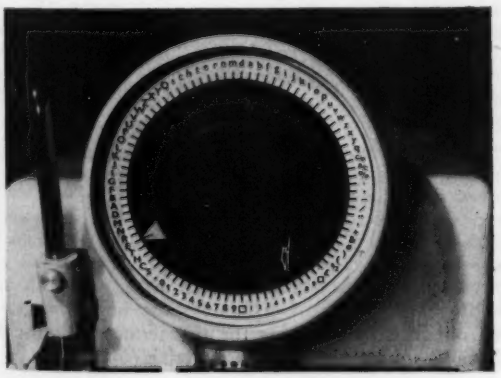
Although both ram head and power unit are normally mounted on the welded tubular chassis with short hose connections, it is possible, for overhead line work, to separate the two units and use hose lengths which can be supplied up to 70 ft. long.

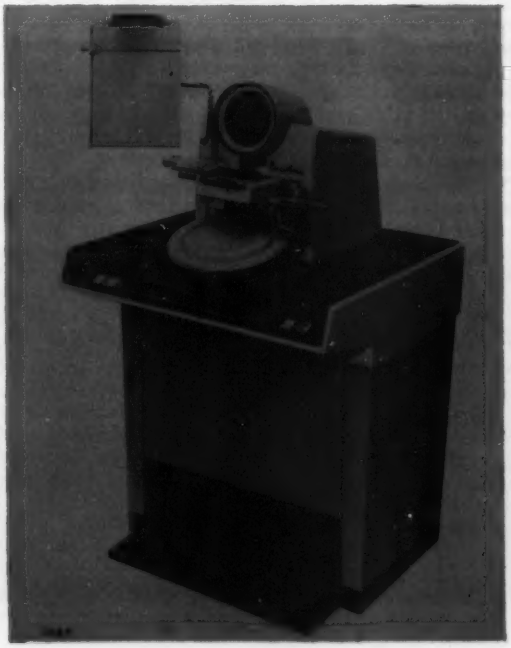


New Dial Design Eliminates Eye-Strain

IN re-designing the Dorchester address plate embossing machine made by Adrema Ltd., A. B. Kirkbride embodied certain features in the dial design according to principles laid down by the Applied Psychology Research Unit and with the aid of advice from the R.A.F. Institute of Aviation Medicine.

In such a machine it is important that the operator is not subjected to eye-fatigue caused by repeated accommodation to varying light intensities from dial, typescript and background. Glare-reflecting finishes have been avoided and the dial is illuminated at the edge. The pointer is painted on a black disc which is in the same plane as the annular ring that bears the characters. Errors due to parallax are thus avoided. The sequence in which the letters are arranged on the dial has been planned for speedy location. Two-handed control over the pointer, which travels either way, enables an average operator to achieve a very high output with ease, only a very light pressure on the console pedal being required to operate the machine. Forward and back spacers are provided as on a typewriter, and the plateholder is mounted on a rack carriage which travels automatically at each section.





PROGRESS IN BATTERY CONSTRUCTION

A report of the recent Battery Symposium held at the Signals Research and Development Establishment of the Ministry of Supply

by D. H. COLLINS, B.Sc.*

THE symposium, which was organised by the Inter-Departmental Committee on Batteries, was the first to be held in this country, although similar events are frequently held in the U.S.A. Thirty papers were presented during the three-day meeting, ranging in subject from pure electro-chemical research through such new developments as fuel cells, solar generators and nuclear batteries to novel methods of operating familiar types of battery.

The papers on lead acid and LeClanche batteries showed that even these familiar types are still the subject of considerable research and development. The replacement of the wood separator in lead acid cells by such materials as microporous rubber or polyvinyl chloride, glass wool filled with diatomaceous earth or cellulosic materials bonded and protected by acid-resistant synthetic resins has led to a significant increase in the life of the cells, particularly at high temperatures.

Corrosion of the positive grids is a further factor which limits the life of lead acid batteries, and replacement of the conventional antimonial lead alloy by new alloys containing reduced amounts of antimony with additions of arsenic, tin and silver either separately or jointly has been shown to be of benefit. In applications where the effects on the negative plates of antimony derived from the positive grids are particularly objectionable, cells with lead calcium alloy positive grids have been developed which are suitable for floating service and a lead tin barium alloy may be satisfactory when deep discharges are required.

The high weight of lead acid batteries has always been a disadvantage, but for some applications a considerable reduction in weight appears to be possible as a result of the development of cells in which the metal grids are replaced by moulded polystyrene grids with a limited number of antimonial or pure lead inserts for conductivity. Such cells show a saving in weight of up to 25 per cent and have satisfactory working lives; they are, however, limited to applications where the discharge current does not exceed the one-hour rating.

Battery containers are frequently criticised as being mechanically weak, and in a U.S. paper the possible use of containers built from plastics materials was considered. Acrylonitrile rubber was found to have good mechanical properties, but its softening point is rather low. Lexan, a polycarbonate plastic, appears to offer greater promise. This material has a softening point of 140 deg. C., is self-extinguishing, and its mechanical properties are such that in many instances it may be possible to ship batteries without any packing, thus saving in part the higher cost of the new material.

A considerable improvement in the output of LeClanche cells is obtained by the use of artificial manganese dioxide in the depolariser. This material, which is produced by the electrolysis of manganous sulphate, gives outputs approximately double that obtained from cells using the naturally-occurring material; it is, however, considerably more expensive. An approximately similar increase in performance can be obtained by substitution of a magnesium alloy for the zinc alloy normally employed for the cell cans. Alloys with aluminium and zinc such as AZ 31c are suitable for this purpose; their use not only increases the output obtainable but also results in improved low-temperature performance. The voltage of such cells is 0·2 to 0·3 volt higher than the normal LeClanche cell, so that for multi-cell batteries a reduction in the number of cells is possible and this can lead to savings in weight and volume of as much as one-third.

Disadvantages of the use of magnesium cells are their higher cost, based in part on higher production costs and in part on the higher cost of materials (the magnesium can alloy and the magnesium bromide electrolyte), and the short delay period before full on-load voltage is developed. In some single-cell applications the higher voltage may also be a disadvantage. The storage life of the cells was stated to be excellent.

The limited storage life of LeClanche cells has always been a drawback to their use, particularly to military users. The Tarana battery developed in Australia appears to offer one solution to this problem. In this development normal LeClanche cells are first dehydrated and then placed in a plastics container of special design. The complete, but inactive, batteries are then stored in a sealed container. When required for use the batteries are placed in a simple, manually-operated vacuum activation device which dispenses the correct amount of water to each cell. After standing for a few hours they are ready for use.

Silver oxide-zinc batteries are outstanding where high capacity to weight and volume ratios are required. Improved performance has been obtained by the use of sintered silver powder plates. Negative plates pose many problems and to suit particular applications zinc oxide, compressed zinc powder, zinc sheet, mesh or wool or even spray-deposited zinc are used. Separators frequently limit the life of this type of cell and some improvement has been obtained by replacing the regenerated cellulose film originally employed by other materials.

* *Admiralty Engineering Laboratory.*

For special single-shot high-discharge rate applications the use of zinc or cadmium anodes with lead dioxide in acid electrolytes was described. Of more general interest were the lead dioxide-magnesium, and silver chloride or cuprous chloride-magnesium, water-activated batteries. Such batteries are of wide application for marine, meteorological and air-sea rescue purposes.

Cuprous chloride is at first sight an attractive material to use in such batteries offering high output, cheapness and light weight. In practice the first two advantages are difficult to realise; the full output is seldom obtainable and the material is difficult and costly to process into suitable electrodes.

By contrast silver chloride, although expensive and corrosive to many metals, is readily cast into plates which are almost metallic in their characteristics and which can be simply fabricated into electrodes of almost any shape and size. In use such electrodes are highly efficient and give a rather higher potential than cuprous chloride, as well as having better storage characteristics.

Inter-cell leakage currents tend to reduce the performance of multi-cell batteries of this type which normally operate in an electrolyte common to all cells. Consequently, the most commonly available types are low-voltage batteries; it was, therefore, interesting to note that two high-voltage batteries, one cuprous chloride and one silver chloride, had been developed. The lead dioxide batteries did not appear to have been so fully developed. All three types of battery use sheet magnesium alloy negative electrodes, although for special applications zinc, in spite of its lower voltage, has some advantages.

Zinc-mercuric oxide batteries are now in quite general use and their small volume makes them very attractive for many applications in spite of their high cost. Figures were shown for one make of cell which indicated that excellent storage characteristics had been obtained. In this type of cell cellulosic materials are employed as a barrier between the two electrodes but microporous synthetic film might replace this in the future and offered possibilities of even better storage life. Effective sealing of the cells is obtained by the use of neoprene or polythene grommets. The other make of cell is similar in construction to a LeClanche cell and is more suitable for high rates of discharge, probably on account of the greater electrode surface areas available. In this cell a neoprene-based adhesive is used in the sealing and a polyvinyl chloride sleeve around the can provides protection and insulation. An interesting development is the production of batteries in which the cells are encapsulated in a cold setting resin; this gives a robust, well-sealed battery which can be manufactured to close dimensional tolerances. A further development is the replacement of the zinc outer can of the cells by a magnesium one; this will not only reduce weight but may also lead to improved storage life.

Alkaline electrolyte accumulators of the nickel-cadmium and nickel-iron types have been in extensive use for many years, although they are not familiar to the general public. Of recent years a new variant of this type of battery has been the subject of intensive investigation. In this new type of cell a highly porous nickel matrix is impregnated with the active materials, whereas in the conventional battery these materials are contained in perforated metal pockets or tubes. The porous nickel matrices are obtained by sintering very pure nickel powder obtained by decomposition of the carbonyl.

This new form of construction lends itself to the use of thin plates and close electrode spacing with consequent reduction in cell size. Very good performance is obtained at high rates of discharge and at low temperatures as a result of the large electrode surfaces available and the good utilisation of active materials.

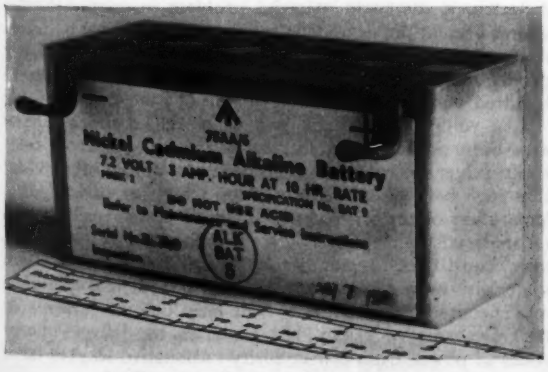
Two types of cell have been developed: a hermetically sealed type with minimum electrolyte, and a semi-sealed type with restricted venting and a larger volume of electrolyte. The former type appears to be satisfactory in small-capacity cells but troubles due to excessive temperature rise may be experienced in the larger sizes, and for satisfactory operation auxiliary temperature control equipment is probably essential. The second type is free from this disadvantage, but is larger and heavier. Both types of cell have the attraction that little maintenance is required.

There are a number of peculiarities in the electrochemical behaviour of the cells which are as yet not fully understood and, in particular, the effects of the inclusion of small quantities of other metallic salts in the electrodes are receiving considerable attention at present. Thin separators are an essential part of the cell construction if good high rate performance and minimum volume are to be obtained. At the same time, adequate strength and resistance to perforation are essential. This is not an easy requirement to meet, but in many cases nylon cloth in combination with other materials appears to be used. In the sealed cells, where absorbent separators are preferred, regenerated cellulose film supported by nylon cloth has been extensively used.

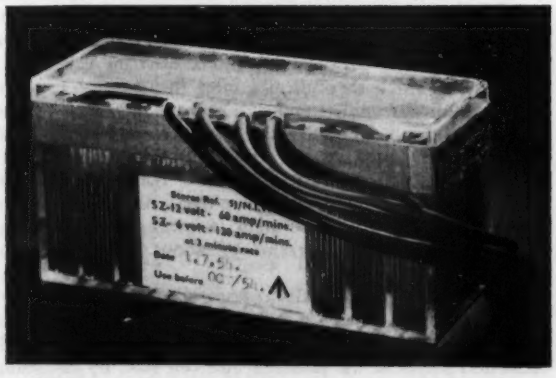
Converting Fuel to Energy

The direct conversion of fuel to electrical energy has long been one of man's ambitions, while today the similar direct conversion of solar and nuclear energy has been added to the list, and it was apparent from two papers presented at the meeting that some success has been achieved in all three fields.

Work on gaseous fuel cells has been in progress for a long time and high efficiencies have been obtained with hydrogen-oxygen cells. Hydrogen cannot, however, be regarded as a commercial fuel and attention has, there-



A Nife six-cell sintered plate battery.



Venner SZ/6/12 silver-zinc battery for guided weapons.

fore, been turned to the possible use of carbon monoxide-hydrogen mixtures such as producer and water gases.

The development of a fuel electrode which was inert to the electrolyte yet an active catalyst for the reaction was a major problem. The development of silverised zinc oxide electrodes provided an answer to this problem. The electrolyte is a eutectic mixture of sodium and lithium carbonates in which concentration polarisation at the oxidising electrode, due to loss of carbonate ions, has been overcome by adding carbon dioxide to the inlet gas. These developments have led to a cell working at about 550° deg. C. which has an open circuit voltage of about 1·1 and which will operate at current densities of up to 150 A/sq. ft. The preferred operating conditions are at about 50 A/sq. ft. when the cell voltage is about 0·75. The energy efficiency under these conditions is about 75 per cent and the thermal efficiencies of the gases about 60 per cent.

Battery design involves the practical problems of keeping weight and volume to a minimum, obtaining large electrode surfaces, avoiding flooding of the pores of the electrode, obtaining a low internal resistance and utilising the fuel at high efficiency. The use of bipolar electrodes reduces volume but complicates the supply and removal of gas. Flooding of the electrodes is avoided by spraying a fine pore coating on the electrolyte face of the electrodes.

Further reductions in size appear possible by containing the electrolyte in a porous sintered magnesia matrix and spraying the electrodes on to the outer faces of the matrix. Cell voltage is largely determined by the internal resistance of the cell and by the composition of the exit gases; if oxidation is almost complete, concentration polarisation is negligible. To avoid the energy loss which is unavoidable if the full amount of gas is used in one pass, cells are operated in cascade and, with eight cells, about 96 per cent of the available energy is converted.

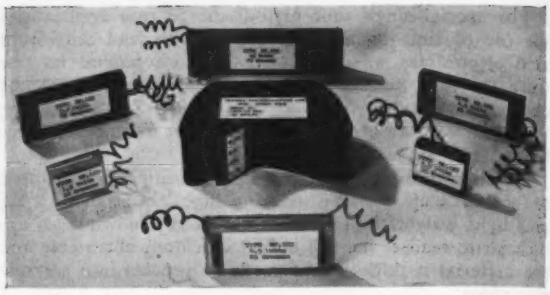
This arrangement is a major advance in battery construction and a practical 2½-kW. battery has been designed. This, coupled with the fact that not only hydrogen-carbon monoxide mixtures but also methane and paraffin vapour can be used as fuels, makes this a very interesting development.

Solar and Nuclear Energy

The conversion of solar and nuclear energy presents different problems. The selenium barrier layer cell has long been known as a photo-voltaic device. Its internal impedance is, however, high and it is harmed by direct sunlight and high temperatures. It is therefore of very limited use. With the development of semi-conductor materials, more efficient cells are possible, since such materials will give cells with lower internal impedances, although there will still be a temperature limitation. The basis of such cells is a p-n junction across which a current flows when incident light excites electrons from the valence to the conduction band. It is thus necessary to obtain semi-conductor materials in which the energy gap between the bands is similar in magnitude to the energy of solar radiation, that is, between 0·8 and 2 electron volts.

Materials which theoretically offer the greatest promise are gallium arsenide and cadmium telluride. These materials are not yet fully developed and most work to date has been based on germanium and silicon semi-conductors, of which the latter is by far the more efficient. With silicon cells open circuit voltages of about 0·7 are obtained, and in bright sunlight, a power of 8 mW./sq. cm. and short circuit currents of about 20 ma./sq. cm. are obtainable.

The efficiency of the cells is controlled by a number of factors including reflection losses, the amount of ineffective light, electron energy losses, resistive losses in the cell, collection losses at the junction and cell size. By enclosing the cells in materials of suitable refractive index, reflection losses can be reduced and by controlling the depth of the junction resistive losses can be minimised. Present cells have efficiencies of about 9 per cent, although 13 per cent has been obtained with laboratory cells.



Venner HT.125 silver-zinc resin-potted batteries, shaped for specific applications.

The cells are thus an attractive although expensive proposition for use in applications where power requirements are low as, for example, in the transistor field. The disadvantage of the intermittent nature of solar energy can be overcome by operating the cells in conjunction with small accumulators; the sealed nickel-cadmium accumulators appear to be particularly well suited to this application. However, in the future thermo-electric generators may be a possible competitor to solar cells, for recently developed semi-conducting materials have much higher thermo-electric powers than any materials previously available, and once the problem of producing these new materials in a form suitable for use in thermo-electric generators has been solved, progress may be rapid. Since maximum efficiency is obtained with the hot junctions as hot as possible, some form of energy concentration will probably be used; such concentration can also be employed with solar cells.

Nuclear radiation can be employed with solar cells instead of visible radiation and offers the possibility of continuous outputs at the same level, but the cells break down within a short time as a result of radiation damage to the semi-conductor. This defect may be overcome, with some loss of efficiency, by causing the nuclear radiation to excite a phosphor, the light from which is then converted by a solar cell.

Two other types of nuclear battery have been produced. The first is, in effect, a self-charging condenser, in which a radio-active isotope, preferably a pure beta emitter, is placed on one electrode and separated from the other electrode by a dielectric which permits passage of the beta particles without permitting discharge of the ionised gas. Such a battery is theoretically capable of giving voltages equivalent to the energy of the beta particles, although such values are not realised in practice. The choice of dielectric is the main material problem in such batteries and at present polystyrene is generally used. These batteries obviously can give only extremely small currents and the production of one watt would probably require several hundred curies of radioactive material.

Low-voltage (less than two volts/cell) batteries have also been produced. In this second type of battery relatively larger currents are obtained as a result of the fact that each beta particle can produce a number of ion pairs. Separation of the ion pairs is achieved by using electrodes of materials with different work functions. Thus a cell may consist of a number of parallel plates of such materials, or p-n junctions of semi-conducting materials may be used. Such batteries will only deliver currents in the microampere range, but batteries to deliver microwatts of power from low-intensity radioactive sources have been built to operate various devices.

ALUMINIUM IN REACTOR ENGINEERING

ATOMIC energy is released as heat when atomic nuclei in the rather unstable heavy metal uranium are shattered by bombardment with neutrons of other atoms. This starts when a mass of fissile uranium is brought near to another similar mass. A direct hit by a neutron on the nucleus of another atom can release two more similar neutrons, so it is possible for the reaction to grow in size and scale to become a chain reaction, and this makes possible the atomic bomb. On the other hand, the whole phenomenon can be controlled: the fast neutrons can be slowed down, materials can be introduced into the system which absorb neutrons or reflect them back (lead, carbon), and the uranium can be reduced or increased in potency as desired. Controlled release of this atomic energy in the form of heat makes possible a nuclear power station.

Aluminium, like other light metals such as magnesium or beryllium, is not much affected by nuclear bombardment. Neutrons tend to pass through it without doing much damage and without their speed or intensity being much changed. Nuclear physicists describe such materials as being "transparent" to neutrons. When a neutron is captured, and causes the metal to become radioactive and emit atomic fragments as radioactivity, aluminium quickly becomes exhausted, and therefore harmless again within a matter of minutes. Its half-life, or the time taken for it to lose half its radioactivity after irradiation, is about two minutes. The other significant physical properties of aluminium and of several other metals useful for nuclear reactors are given in the table. These characteristics suit aluminium very well for certain purposes in the design of nuclear reactors. It can be used as a sheath for the uranium rods in the pile which must be protected from the atmosphere or the cooling medium. The aluminium can be placed in the heart of the reactor without absorbing neutrons and thus detracting from the efficiency of the uranium fuel.

Because of its good thermal conductivity, it facilitates the transfer of heat from the uranium rods through the sheath to the coolant, which removes the heat from the reactor for conversion to electricity. Also, because it is transparent to neutrons, aluminium is a useful outer container for a reactor used for research purposes: neutrons are allowed to emerge through the aluminium and to irradiate substances under heat.

In contrast to other light metals, aluminium combines chemically with uranium at a relatively low temperature (175 deg. C.). This sets a limit to the temperature at which a reactor using aluminium as a canning material for the fuel can be operated. This can sometimes be turned to good account by mixing the uranium fuel with aluminium in order to modify its fission properties for control purposes.

The strength of the material at elevated temperatures, its immunity to corrosive attack by air, water, heavy water, carbon dioxide and other materials encountered in a reactor are important to the reactor engineer.

Aluminium is unaffected by contact with air or carbon dioxide, both of which are used as cooling media in reactors, up to near its melting point (658 deg. C.), and it is not attacked by pure water or heavy water at ordinary temperatures, or up to 150 deg. C. Studies have led to the development of aluminium alloys containing nickel and iron that can withstand the action of water at temperatures up to 300 deg. C. and the loss of mechanical strength in pure aluminium does not become noticeable until the temperature approaches 150 deg. C. These characteristics, well known to the reactor engineer, have given aluminium a definite place in the list of materials to be considered for various types of reactor. It should be added that the engineer also knows aluminium can be shaped and welded easily, is readily available and relatively inexpensive.

IRRADIATED ALUMINIUM ALLOYS—When a fast neutron penetrates a metal and hits an atom it may knock the atom out of its place in the regular symmetrical pattern of the crystal lattice; this can lead to permanent distortion of the crystal structure as well as to other radiation damage. The effects are similar to those of work hardening where the metal increases in strength, shear stress and yield point, but decreases in its capacity to sustain further deformation, and in thermal and electrical conductivity.

Below are shown effects of neutron bombardment. It should be noted that, as would be expected, the effects are much more marked on the soft materials than on those that were work-hardened or heat-treated before being irradiated.

Extracted from *The Aluminium Courier* (September, 1958) by permission of the Aluminium Development Association.

*Effect of neutron bombardment on the strength of aluminium and its alloys**

		Yield Strength (0·2% proof stress) p.s.i.	Tensile Strength p.s.i.	Elongation on 2 in. %
Al–99% min. (S1C–O	Control specimens	6,800	13,600	38·2
	Irradiated specimens	17,100	26,000	21·2
½H–Al (S1C–½H)	Control specimens	16,600	17,300	6·0
	Irradiated specimens	24,000	26,000	5·5
Al–2% Mg. (NS4–O)	Control specimens	14,700	29,200	34·0
	Irradiated specimens	22,900	37,400	30·6
Al–2% Mg. (NS4–H)	Control specimens	29,500	36,000	11·2
	Irradiated specimens	36,400	44,700	14·0
H10 type alloy (HS10–O)	Control specimens	9,460	18,050	28·8
	Irradiated specimens	25,600	37,300	22·4
H10 type alloy (HS10–WP)	Control specimens	38,500	45,000	17·5
	Irradiated specimens	44,400	50,600	16·2
Al–3½% Mg. alloy	Control specimens	47,800	54,700	8·8
	Irradiated specimens	50,800	57,800	12·5

* After Steel & Wallace, U.S.A.E.C.

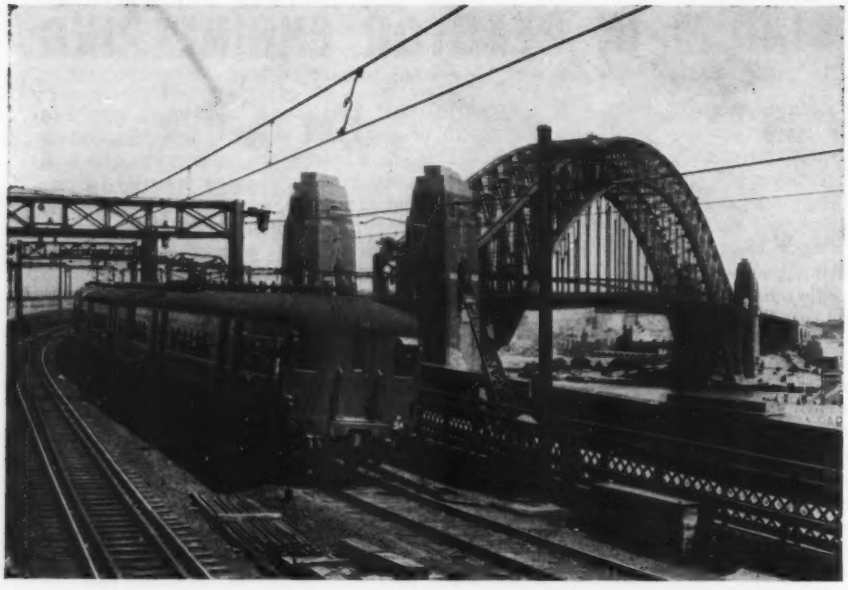


Fig. 1. New South Wales suburban train fitted with Ferodo asbestos-based brake blocks.

ASBESTOS IN THE SERVICE OF MODERN RAILWAYS

Current modernisation of railway systems is resulting in an increase in the use of asbestos-based components. This article surveys recent trends in this field

by C. Z. CARROLL-PORCZYNSKI*

ASBESTOS-BASED products in various forms have been used for a number of years by railways both in the U.K. and abroad. With the current modernisation programme of British Railways, they are likely to play a very significant part, because of their great strength, resistance to weather, corrosion, fire, heat, acids, alkalis, vermin and fungal growth.

SPRAYED ASBESTOS—This is a simple method of applying asbestos fibre directly to the steel shell of railway cars which was developed some twenty years ago to provide an efficient insulation, sound deadening, anti-drumming and anti-condensation medium. This process, known as the Limpet, has since been developed and some improvements have recently been patented,[1] but basically it is as follows:

The spraying apparatus employed for coatings consists of a light, portable feeder which delivers a constant stream of asbestos fibres to a fan, which, in turn, blows the fibre down a flexible tube to a nozzle. As the fibre stream issues from the nozzle it meets a finely atomised spray of bonding liquid. The atomisation is effected by compressed air and is regulated at the spray gun to give the correct amount of liquid at a predetermined rate. The resultant mixture remains plastic up to a period of two hours and the surface may be flattened or shaped as required, the whole becoming set in approximately eight hours.

As an insulant in railway carriages, sprayed asbestos is frequently applied between double floors and on the underside of steel or alloy flooring sheets. It has the added function of reducing the transmission of track noise.

The property of asbestos in absorbing liquids has been utilised with excellent results as an anti-condensation agent applied to the inner surface of the outer steel shell of railway cars (see Fig. 3). The air space created between a cold exterior wall and warm inside panelling of the carriage acts as a condenser of water vapours. Water formed on the cold metal surface passes into the inner warm layer of asbestos coating and re-evaporates to the surrounding air if suitable ventilation is provided.[2]

The usefulness of sprayed asbestos is appreciated in the current modernisation programme of British Railways, where sprayed asbestos is finding increasing use by designers of diesel, diesel-electric and electric locomotives (see Fig. 2).

Asbestos Textiles

Textiles made from asbestos find numerous applications on railways because of their good mechanical properties coupled with excellent heat, fire and chemical resistance.

* *Manager, asbestos division of Metal Traders Ltd.*

A fairly recent example of their successful application in the U.K. is asbestos-nylon-reinforced vestibule or corridor cloth. This is a material of approximately 30 oz./sq. yd., usually p.v.c.-coated on the outside and coated and scraped on the inside.[4] Having an inorganic base, it is completely fireproof and is characterised by great resistance to flexing and abrasion. The two latter properties are of great importance, as in actual working conditions the vestibule cloth is constantly subjected to flexing and rubbing.

It is probable, however, that the good performance of this material could be further improved by the employment of a somewhat thinner cloth and a more uniform p.v.c. coating on both sides.

Another form of asbestos textile finding extensive use is asbestos tape. In this form, asbestos serves as a heat insulation on steam pipes and also as a fireproof, mildew- and rot-proof insulation on underground electrical cables. A recent B.T-H. patent embodies the use of asbestos tape for high-voltage circuit bushing assemblies. In this case, the yieldable insulating layer is provided by winding on to the conductors one or more layers of asbestos tape painted with a conductive liquid suspension of carbon.[5]

Frequently, where fire hazard exists, electrical cables are insulated with thin layers of asbestos rovings. One of the old-established forms of asbestos textiles on railways is asbestos mattress locomotive insulation, made usually from an envelope of blue asbestos cloth filled with loose asbestos fibres, stabbed at intervals with asbestos sewing twine to hold the filling in place. It is used for the insulation of locomotive boiler barrels, steam domes, fire boxes, throat plates and the steam cylinders. A commonly-used product of this kind is Pluto, made by Cape Asbestos Co.

A new material of this type developed by J. W. Roberts Ltd. comprises a clothing plate to which is attached one or more insulating mattresses which, either singly or together, form a shallow box, the perimeter walls of which are of such a depth that when the unit is in position they seal the space between the boiler or fire box, and the body of the mattress forms a substantially still air space within the box.[6]

Because of its excellent chemical and heat resistance, blue asbestos cloth is also employed for smoke chutes at B.R. locomotive sheds and for the exhausts of diesel locomotives.

An interesting use of asbestos textiles on railways was developed by Philplug Products Ltd. This is a sleeper compound consisting of asbestos fibre or asbestos rope and cementitious powders which, when moistened, are packed into the worn hole in the sleeper. It is used for rebushing worn holes in timber sleepers so that rail screws or spikes may be refixed into existing holes, thus prolonging very effectively the life of timber sleepers.

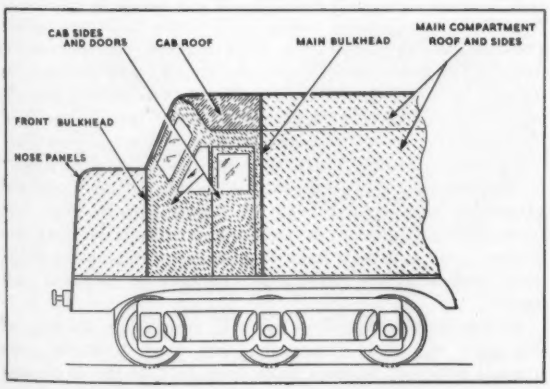


Fig. 2. Principal uses of asbestos materials in B.R. diesel railcar.

Typical physical properties of asbestos-based plastics

	Railko AL.2	Railko AL.6
Tensile strength, p.s.i.		
Along laminates	7,000	8,500
Through laminates	5,000	6,000
Ultimate compressive strength, p.s.i.		
Flatwise	28,000	30,000
Edgewise	10,000	12,000
Shear strength, p.s.i.		
Flatwise	5,000	6,000
Impact strength, ft. lb.		
Flatwise lengthwise	2·5	2·5
Edgewise crosswise	1·2	2·0
Cross-breaking strength average, p.s.i.		
Along laminates	6,000	7,000

Asbestos-Based Plastics

One of the well-established types of asbestos-reinforced plastics available is Ferobestos, made by laminating impregnated asbestos cloth or fibre with a thermosetting resin. Its main characteristics are high strength/weight ratio, low thermal conductivity and high temperature resistance, low moisture absorption, good dimensional stability and good chemical resistance.

Plastics of this type are particularly suitable as a bearing and anti-friction material, as in these applications they do not require special lubricants; their excellent wearing properties and ability to withstand shock loads extend their service life in most cases to outlast metal or other plastics bearings.

A typical example of such plastics used on railways is an axle box horn plate liner. It has been found that the vertical reciprocating motion of the axle box in its guide produces considerable wear on the steel or phosphor-bronze opposing surfaces and that the use of the asbestos-plastics horn box liner has resulted in a substantial reduction of this wear.[7]

Bogie bolster pads are yet another example where the problem of excessive wear coupled with the difficulty of regular lubrication have been solved by employing these asbestos-based plastics. In this application the excessive wear of metal parts is caused by an intermittent rubbing action of the bolster sides with the frame of the bogie during the oscillating movement of the vehicle. For the same reasons, asbestos-based plastics are used as rubbing faces between corridor coach ends, and as the rubbing bar across which the auto-coupler moves. They also serve as bushes for swing links and pull rods on brake gears. Their use is not only confined to carriages, but extends to heavy-duty components on the bogies and pony trucks of locomotives and also in signalling gear.

Since these materials do not require lubrication, they have met with great success as guide rollers on the sliding doors of underground stock where they have eliminated the hazard of contaminating passengers' clothing.

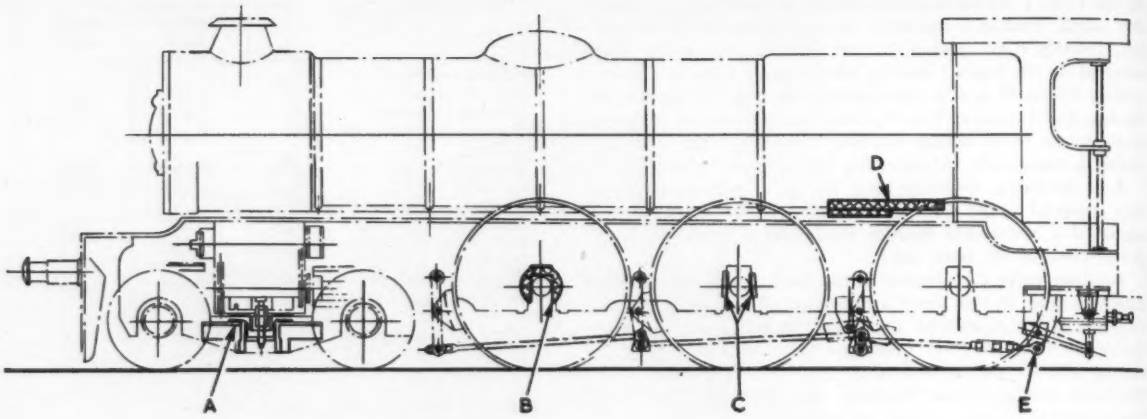
A further application of asbestos-based plastics is on the section insulators of overhead cable systems.

Among those firms specialising in the development and production of such materials is the Railko Co. Some of the physical properties of this company's products commonly used for rail service are shown in the table on this page.

Other Plastics Materials

With the progressive electrification of railways and the growing use of electrical signalling systems there is increasing demand for electrical insulating materials.

Recently a rail butt joint has been developed which con-



sists of metal plates to each side of which is secured a plate of an electrical insulation material made from polyester resin and inorganic fibres.[10]

Another recent invention concerns a device which ensures complete electrical insulation of the rail without adversely affecting the attachment of the latter to the sleeper. This takes the form of a rubber padding which provides insulation and acts as a resilient support for the rail.[11]

A very interesting cushioning composition for railroad ties was recently developed by the Standard Oil Co. It consists of 15-35 per cent by weight of co-polymer of styrene and isobutylene, 15-35 per cent by weight of petroleum asphalt and 30-70 per cent by weight of asbestos fibres.[12]

Brake Blocks and Friction Linings

The increasing speeds of locomotives and rolling stock call for more efficient friction materials. It has been found in the past that the traditional type of cast-iron shoe can cause damage to vehicle wheels by excessive wear and heating of the wheel tread. Recently, Westinghouse Air Brake Co. developed a moulded composition friction material which is claimed to have better performance under variable speeds, temperatures and weather conditions and provide longer wear life and less abrading effect on wheels than the traditional cast-iron shoe.[8]

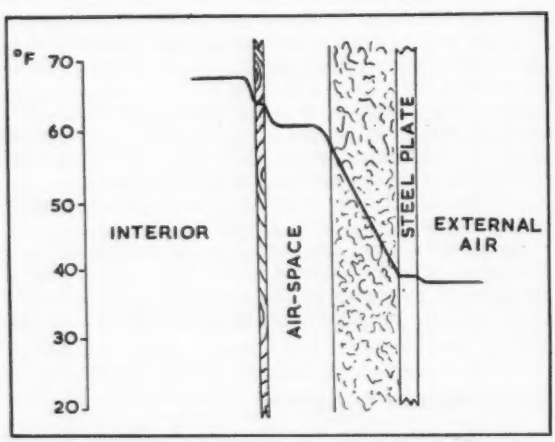


Fig. 3. Temperature drop from the warm inside to the cold outside air through 1-in. insulation overdrawn with panelling.[3]

The ingredients in making such composition material for brakes shoes are:

Unvulcanised powder rubber ...	4-10% by weight
Phenol-formaldehyde resin ...	8-15%
Short asbestos fibres	12-20%
Carbon black	0-10%
Cast-iron chips	65-75%

In the patented process a reinforcing element may be combined with the shoe body during the moulding operation.[9]

A similar type of brake block is made in the U.K. by Ferodo Ltd.

A particular advantage claimed for these brake blocks is that their friction is unaffected by water and, because of their resistance to scoring and abrasion, they give greater wheel life and silent braking. An important advantage on electrical systems is that the wear-product (unlike the metallic dust caused by cast-iron shoes) is non-conducting.

The extensive use of diesel locomotives which transmit their power through a clutch also calls for asbestos-based disc or cone clutch facings.

Asbestos Cement

In view of the renewal each year by British Railways of four million track sleepers, the development of a sleeper with an increased life could result in considerable economies. For this reason it is worth noting the claims made by Eternit Co., manufacturers of asbestos-cement sleepers which are said to be commanding the ever-increasing interest of railway authorities in many countries. It is claimed that these sleepers are not liable to deterioration due to weathering and always retain their monolithic structure as an everlasting impermeable, uninflammable material, immune from termite attack and any tendency to soften. Their life is said to be almost unlimited. They are built from a highly compressed wafer of thin layers of a homogeneous mixture of cement and asbestos fibres. Serrated steel rods are laid longitudinally within the sleeper to provide an additional reinforcement and to keep the gauge constant in the event of a de-railment. The rail fastenings are pre-set in the sleeper to ensure that the proper gauge is always held, facilitating perfection in alignment and levelling, and thus resulting in reduced rail wear.[13]

So far, British Railways are not employing sleepers of this type, but it is interesting that over 2,500,000 prestressed concrete sleepers have been laid in the U.K. and that in these sleepers asbestos is being used in the form of inserts for screw or spike rail fastenings.

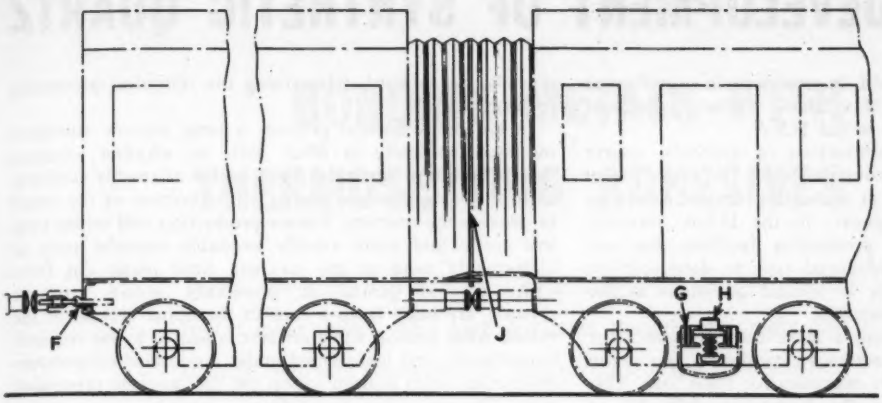


Fig. 4. Asbestos in B.R. steam locomotive and coach: A—bogie slide and centre pivot liners; B—axle box face liner; C—axle box guide liner; D—expansion angle liner; E—bushes for brake gear pivots; F—drawbar rubbing block; G—carriage bogie bolster side rubbing pad; H—carriage bogie bolster bearer pad; J—corridor end facings.

Coating, Jointing and Sealing Compositions

Asbestos fibres are widely employed in various bituminous roof coatings, insulation sealers, corrosion-resistant mastics and maintenance paints, all of which are being used on railways. These compositions are made by blending a vehicle, filler, auxiliary resin, pigment and solvent.

The most popular vehicle is asphalt, either in a natural state such as gilsonite, or asphalts obtained from the distillation of petroleum crude oils. Other vehicles include coal tar, fish oil, fatty acid pitches and resins, but asbestos is by far the most important filling and reinforcing material. It is used to improve weathering characteristics and toughness, to control consistency and sag and to produce a thick film.

The purpose of the pigment is to add decorative protective value to a coating. Aluminium pigment is quite popular because a reflecting point of low moisture vapour transmission rate can be produced with only a slight increase in cost.

A specification[14] for a special paint system for railway overhead systems incorporating this type of pigment is:

Tinted first coat	*Untinted second coat*
26·25% asphalt cutback (63% solids) ...	26·25%
18·25 fish oil	18·25%
14·50% 5R asbestos	14·50%
1·25% diatomaceous silica	2·75%
1·50% red iron oxide	—
38·25% mineral spirits	38·25%

An interesting new anti-corrosive paint composition which can be applied to moist or wet metal surfaces without pilling or skinning and incorporating asbestos fibres has been developed by Armour & Co.[15]

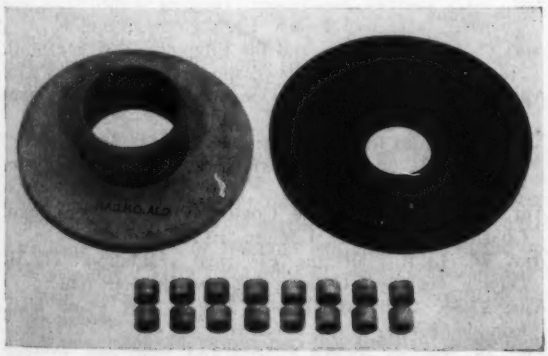


Fig. 5. Asbestos-based components in rail service. *Above left:* Vertical sleeve and centre pivot liner used in Glasgow electrification scheme. *Above right:* Centre plate wearing pad (South Australian Railways). *Below:* Bushes in use on B.R. diesel railcar.

Various coatings are employed on railways for repairs and maintenance purposes as well as in bridge construction. Such coating compositions[16] may consist of:

70 lb. asphalt cutback (70% solids)
12 lb. asbestos fibre 7R
18 lb. mineral spirits.

In the U.K., Asbestumen, a bitumen-asbestos sealing compound introduced by the Expandite Co., is being applied on railways to protect the base of steel masts supporting the overhead electric cables from water and corrosive atmosphere. The same material is being used as a sealer in cavities and cracks in railway tunnels and bridges.

Stewarts & Lloyds Ltd. have developed a covering for protecting metal pipes and cables against corrosion, based on asbestos and incorporating a paste composed of paraffinic hydrocarbon and corrosion-inhibiting chemicals.[17] Berry Wiggins & Co. have produced a special asbestos based glazing compound, called Kingsnorth, and an asbestos-containing bitumen waterproofing composition known as Aquaseal.

A wide range of similar asbestos-containing bituminous composition is also being produced by Kelsey Industries Ltd.

The great activity in the field of asbestos-based jointing and sealing compositions is clearly reflected in numerous recent patents taken out by various companies.[18–22] Though by no means a comprehensive account of asbestos applications on railways, this brief review of some recent developments in this field clearly indicates that asbestos and asbestos-based products are almost indispensable to modern rail transport and are likely to play an increasingly important role in the future.

REFERENCES
1. B.P. 798,333 (Insulation). J. W. Roberts Ltd.
2. *Sprayed Limpet Asbestos* (J. W. Roberts Ltd.).
3. "Influence of Insulation Design on Condensation and Corrosion", N. L. Dolbey. B.I.S.R.A. Atmospheric Corrosion Sub-committee, October 25. 1955.
4. Vestibule Cloth. Prov. Spec. P. 6629, March 2, 1956. C. Z. Carroll-Porczynski.
5. B.P. 793,974 (Electric insulating bushing assemblies). B.T.-H.
6. B.P. 767,332 (Locomotive insulation). J. W. Roberts Ltd.
7. *Ferobestos Plastics for Railway Application* (J. W. Roberts Ltd.).
8. B.P. 777,768 (Brake shoe). Westinghouse Air Brake Co.
9. B.P. 791,742 (Improved brake shoe). Westinghouse Air Brake Co.
10. B.P. 775,256 (Rail butt joints). Hans Stager.
11. B.P. 801,912 (Electrical insulation). R. P. Sonneville.
12. U.S.P. 2,688,005 (Cushioning composition). Standard Oil Dev. Co.
13. *Italit-Mazza Railway Sleepers* (Eternit Co.).
14. Steel Structures Painting Manual, **1**, 252.
15. B.P. 782,296 (Anti-corrosive paint). Armour Co.
16. Roof Coating. Fed. Spec. SS-R-451.
17. B.P. 683,207 (Pipe coating). Stewarts & Lloyds Ltd.
18. B.P. 775,303 (Pointing material). G. K. Findlay.
19. B.P. 777,067 (Expansion joint filling material). Semtex Ltd.
20. B.P. 783,327 (Jointing material). Chemieprodukte G.m.b.H.
21. B.P. 767,039 (Sealing and jointing material). G. Wimpey & Co. Ltd.
22. B.P. 800,282 (Protective coating on concrete and ironwork). P. Lechler.

DEVELOPMENT OF SYNTHETIC QUARTZ

A DEVELOPMENT said to compare in significance with the production of synthetic rubber, nylon and rayon has been announced in the U.S.A.

Details of pilot-plant production of synthetic quartz crystals for telephone communication purposes were revealed in a paper given at a meeting of the American Institute of Chemical Engineers in the U.S.A. recently. The paper described the production facilities that are believed to be the most advanced type to date and are now growing large crystals in limited quantities at the works of the Western Electric Co.

The Bell telephone system, a large user of quartz for filters, oscillators and frequency standards, has been interested in synthetic quartz processes for some time. This interest has resulted from the increasing difficulty in obtaining large crystals of natural quartz and from the generally unstable market conditions. Quartz suitable for use in communication devices comes mainly from Brazil, where its mining is carried out on an essentially free-lance basis. An apparent depletion of larger natural quartz crystals has caused critical shortages at times, particularly during the Second World War when it was found necessary to develop and use other piezo-electric materials, notably ethylenediamine tartrate as a quartz substitute, for use in sonar and communication devices.

Synthetic quartz provides a number of advantages over natural quartz in addition to its availability in any quantity and size. Seeds can be cut to provide grown crystals which can be sawn in the most efficient manner. Also, synthetic quartz has natural crystal faces which allow easier orientation of the stock for cutting into crystal units. It has none of the foreign inclusions which usually occur in natural quartz, and it can be produced without either optical or electrical twinning. It is estimated that the greater yield resulting from these improvements is at present at least two and a half times that of natural quartz.

The hydrothermal process has been widely investigated on a laboratory scale for several years, and quartz crystals about $\frac{3}{4}$ in. square by $1\frac{1}{4}$ in. long, and larger, have been grown at Bell Laboratories. The processing equipment has been scaled up for pilot-plant investigation, and quartz crystals up to 2-3 in. in each cross-section dimension and 5-6 in. long have been grown in this equipment. Operations have not been directed toward growing the biggest possible crystals, but toward determining the optimum processing parameters.

In the hydrothermal process, a long, narrow autoclave mounted vertically is filled with an alkaline solution, usually sodium hydroxide. Small pieces of readily available natural quartz are then placed in the bottom of the vessel to provide the nutrient. Future production will utilise even less costly and more readily available material such as high-quality sand as the nutrient. Seed plates cut from either natural quartz, or previously grown synthetic crystals, are hung from a rack in the upper section of the vessel. After sealing, the autoclave is heated to the required temperature, and maintained under a constant temperature differential from bottom to top for the requisite processing time. This period has varied from a week to several weeks, depending on the experiment being performed.

Economical growth rate considerably in excess of 0·060 in. per day has been achieved. Since growth occurs primarily in one dimension, flat seed plates are used which effectively become thicker but change little in other dimensions. The rate of growth varies with each of a number of conditions, including the temperature differential between nutrient and seed plate area, the alkalinity of the solution, the temperature and per cent fill (or pressure).

Operation of the hydrothermal process depends on the maintenance of a temperature differential between the nutrient area and the seed plate area. The nutrient dissolves in the hotter lower region and is carried by convection currents to the cooler upper region. The lower temperature here leads to a supersaturated condition in the nutrient solution, which causes the dissolved quartz to redeposit on to the seed plates in single crystal form.

One of the main problems which appeared in scaling up the pilot-plant equipment was that of finding a suitable closure for the autoclaves. The laboratory vessels were simply welded tubes supported by capped, high-pressure piping. A repetitive closure was required for the larger autoclaves and a satisfactory closure was developed which gives a tighter seal as the pressure inside builds up.

The combination of high temperature and pressure conditions present in this process is believed to be one of the most severe encountered in any process industry at present. This gave rise to a number of material selection and equipment design problems.

Designers' Diary

Mar. 17-21. English Electric Valve Co. Exhib. Kensington Palace Hotel, London.

Mar. 17-21. Electrical Engineers' Exhib. Earls Court, London.

Mar. 20. Inst. Prod. Eng. "Engineering Ceramics" (C. G. Martin). S. Wales Inst. of Engineers, Park Place, Cardiff. 7 p.m.

Apr. 3. Plastics Inst. "Developments in Processing and Application of Acrylic Resins" (L. Griffiths). Textile Inst., Manchester. 6.45 p.m.

Apr. 16-30. Engineering, Marine, Welding and Nuclear Energy Exhib. Olympia.

Apr. 6. I.E.E. "Artificial Fibres" (P. T. Standring). Royal Institution, Liverpool. 6.30 p.m.

Apr. 6-9. Radio and Electronic Component Show. Grosvenor House and Park Lane House, London, W.1.

Apr. 7. I.E.E. "Recent Advances in Speed-Changing Motors" (G. H. Rawcliffe). Carlton Hotel, Edinburgh. 7 p.m.

Apr. 7-17. Factory Equipment, Heating Ventilation and Thermal Insulation Exhib. Earls Court, London.

Apr. 13. I.E.D. "Plastics and the Engineer" (W. J. Grant). N. Architectural Hall, Newcastle upon Tyne. 7.15 p.m.

Apr. 16-17. Inst. Prod. Eng. Conf. on Aircraft Production. University of Southampton.

Apr. 17. Plastics Inst. "Fire- and Heat-resistant Materials" (W. Wilson). James Watt Memorial Inst., Birmingham. 6.30 p.m.

Apr. 17. Metal & Plastic Coatings Assoc. Symposium. Charing Cross Hotel, London. 10.15 a.m.

Apr. 20. I.E.E. "Silicone Electrical Insulation" (J. H. Davis). Technical College, Scunthorpe. 6.45 p.m.

Apr. 27-30. Corrosion Exhib. Royal Hort. New Hall, London, S.W.1.

Apr. 29. Inst. of Metals & Iron and Steel Inst. Powder Metallurgy Group. "Theoretical Aspects of Sintering". Church House, London, S.W.1. 9.30 a.m.

Apr. 29-30. I.E.E. Convention on Thermonuclear Processes. London.

BONDING METALS WITH THERMOSETTING ADHESIVES

This is the second of two articles dealing with the bonding of metal structures. This part discusses the pretreatments and testing methods necessary for the successful use of adhesives

by E. J. CATCHPOLE, B.Sc. (Eng.), A.F.R.Ae.S., M.I.A.S.*

IN a previous article it was shown how the use of thermosetting resin adhesives compares with riveting and other conventional methods of joining structures. The actual procedures used in bonding are, however, of direct interest to the design engineer, for without an appreciation of the pretreatment process, the method of application and curing, he may specify the use of a technique that will not achieve the results he has in mind.

Good results with these resins naturally demand care in bonding work. The most important factors in obtaining satisfactory results are adequate and careful pretreatment (and maintained cleanliness to preserve the surface thus obtained) and application of sufficient heat and pressure during curing.

PRETREATMENT—Adequate pretreatment is important whatever the adhesive used; its effect on peel strength is most marked, but there is also an appreciable effect on shear strength, and especially in reducing scatter of strengths.

Much work has been carried out on suitable pretreatment of aluminium alloys. Although more than one procedure has been developed, the following is very reliable and has not yet been superseded:

1. Degrease in trichlorethylene vapour.
2. Pickle in sulphuric acid/sodium dichromate solution (British specification DTD 915B).
3. Wash in cold water.
4. Wash in warm water (not hotter than 60 deg. C.).
5. Air dry.

Where very dirty and greasy parts are to be bonded under production conditions, a detergent wash is often used between the first and second operations. Anodising may also be included in the sequence.

A further interesting operation is blasting with fine particles before the pickle. The special apparatus which has been used is known as Vacu-blast (developed by the company of that name). With this, a nozzle blows aluminium oxide powder on to the surface, using compressed air, and sucks the particles away through a concentric ring. In this way, the blast can be applied in the open shop. Table 1 gives the results of some comparative tests, which indicate the improvement of peel strength by using this process.

It must again be emphasised that these processes (detergent wash and vapour blast) are optional additions to the pretreatment and do not in any sense replace the other operations.

* *Manager, bonded structures division, CIBA (A.R.L.) Ltd.*

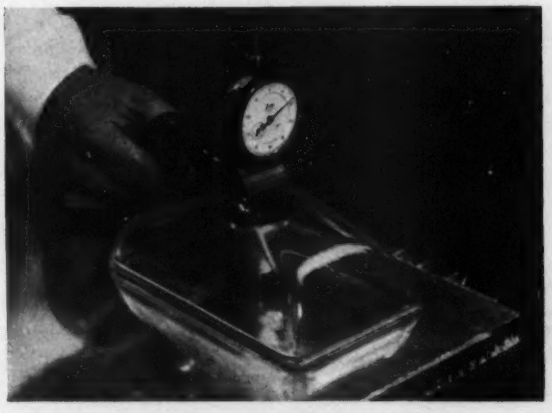


Fig. 1. A Ciba vacuum tester for checking the bond of honeycomb sandwiches.

Most bonding of metals has been done with aluminium, but similar methods apply to other structural materials. Those for stainless steel and titanium are given in Table 2, but pretreatments for both these materials are still under development.

Chance-Vought Aircraft Inc. have had very extensive experience in the bonding (with Redux) of magnesium and its alloys, and before applying adhesives they use the procedure shown in Table 3.

For the bonding of brakes, and for some other commercial applications, shot-blasting is often used in place of pickling because of its convenience in use.

After the appropriate pretreatment processes, the surface thus obtained must be preserved until bonding takes place. Care in handling the parts is the first requirement, and this means particularly that the bonding surfaces should not be touched by hand; cotton gloves may be used to avoid this. General shop cleanliness is also a considerable help at this stage. Undoubtedly, however, the best way of preserving the surface is to apply the adhesive soon after the pretreatment process, and preferably within about an hour. This may not be practicable, especially with film adhesives, but it can usually be done with the liquid and powder process.

APPLICATION OF THE ADHESIVE—In the case of liquids, application is usually by brushing or spraying; spraying is generally quicker where high production rates and large areas are involved, but it should be remembered that the

additional solvents usually needed to facilitate spraying must be dried off carefully, and more than one coat may be necessary.

In the Redux process, for example, the separate application of liquid and powder enables a thick layer of adhesive to be applied easily, and solvent drying is not a major problem even if the liquid is sprayed.

Film adhesives are also very simple to apply.

With Araldite Type 1 it is necessary to melt the sticks of adhesive on to the metal, but again this provides a solvent-free application.

CURING THE ADHESIVE—It is often said that the ideal metal bonding adhesive would cure at room temperature and require no pressure. In fact, however, these features are not generally practicable or desirable. A hot-setting adhesive, such as that based on phenol-formaldehyde, has the important advantages that it has virtually unlimited pot life and that its curing is initiated only at will, even after application. The first of these advantages is of obvious significance, and the second not only enables more flexible operation of the bonding shop (delays between application of the adhesive and insertion in the bonding fixture), but is indispensable when the adhesive is used for assembly purposes (as, for example, in Blume's work in Germany, mentioned later).

So far as pressure during curing is concerned, it is necessary to supply not only the bonding pressure required by the adhesive itself, but also sufficient pressure to ensure accurate mating of the surfaces. For light gauge, or honeycomb sandwich, structures, this latter is not of much significance, but where heavier gauges (such as those most frequently used in primary aircraft structures) are concerned, additional pressures of up to 200 p.s.i. may be involved.

Thus for most structural applications it is necessary to supply heat (say 140-200 deg. C. depending on the adhesive) and pressure, say, 10-250 p.s.i. One method of supplying these, which has been adopted by Sud Aviation in France, is to employ clamping jigs and conventional ovens, but more usually presses, steam- or electrically-heated and water cooled, or autoclaves are used.

Press bonding provides a reliable and rapid method of bonding flat panels. For curved parts, however, tooling is simplified by the use of an autoclave, since mating tools are unnecessary.

Fig. 2. A Ciba drum peel test being carried out on a Hounsfield Tensometer.

TABLE 1. Effect of including Vacu-blast in the pretreatment of bonded joints (preliminary results)

Test	Degreased and Pickled Specimens	Degreased, Vacu-Blasted and Pickled Specimens	
	Mean Load (lb.)	Mean Load (lb.)	Increase %
Shear: 16 gauge 24 S-T, ½ in. overlap	2,978	2,935	—
Bend: 16 gauge 24 S-T, ½ in. overlap	228	250	14
Peel: 20 gauge 610 D.T.D. ARL Drum method	51	72	39

TABLE 2. Pickling processes for stainless steel and titanium

Stainless Steel	
Concentrated hydrochloric acid ...	50 parts by weight
30% Hydrogen peroxide	2 " " "
Formalin	10 " " "
Water	45 " " "
Immerse parts for 10 min. at 60–65°C.	

Titanium	
For removal of light oxide film (if present)	
50% hydrofluoric acid or sodium fluoride	... 4% by volume
32% hydrochloric acid	20% " "
Water	76% " "
Immerse parts for 5–10 min. at 50 deg. C.	
For etching	
50% hydrofluoric acid or sodium fluoride	4% by volume
65% nitric acid	20% " "
Water	76% " "
Immerse parts for 5–10 min. at 50 deg. C.	

Redux has a very short, low-temperature cure, requiring about 30 min. at 145 deg. C. For this case, typical cure cycles (from loading to unloading) are: for a press, 1 hour; for an autoclave, 2¼ hours; i.e., the press gives a considerably shorter cycle, since heat transfer to the component is much more rapid. It must be emphasised that recommended curing times are based on actual temperature at the glue line. Great care must be taken, by means of thermocouples placed in the component, that all glue lines reach the prescribed temperature before the commencement of the cure is recorded.

Where low pressures only are required, as in very light-gauge (0·02 in. or less) structures, or for honeycomb sandwiches, vacuum pressure is generally the most convenient. The component, covered with a rubber blanket, is placed in an oven or on a heated table and the air is drawn out from under the blanket by a vacuum pump. The curing of even fairly complex parts can be effected with very simple apparatus in this way.

Special heating arrangements for bonding parts on aircraft assembly jigs may be used. Such methods have not been widely developed, but recently Professor Blume's team in Germany has, using ingenious but relatively simple methods, bonded the whole outer wing of their aircraft in an oven in one curing operation, the assembly jig being also the bonding jig. The jig proved to be remarkably simple in view of the fact that, apart from assembly and bonding, pretensioning of the skin is also carried out on it. As mentioned earlier, it is important to be able to commence the cure of the adhesive at will, as various operations, and especially pretensioning of the skin, must be carried out after application of the adhesive, but before

its cure. Certainly this is a development which paves the way for even more interesting applications of metal bonding in the future.

Quality Control and Inspection

The basic problem in ensuring structural integrity of a bonded joint is that there is no method yet available which gives a fully reliable inspection after the bond has been made. Thus generally reliance is placed on (1) very careful control of the process; (2) the use of test-pieces bonded with the component; (3) inspection of the appearance of the bonded component; and (4) occasional complete destruction of the component itself. These methods may or may not be supplemented by (5) sonic or ultrasonic tests on the finished component.

In spite of this basic difficulty, correct application of the first four methods above gives very reliable results. For example, 22,500 stringer-skin panels were produced for the primary structure of the de Havilland Dove, and there is not a single record of a failure of a bond.

All the same, a reliable non-destructive test is most desirable, and it is worth examining some of the progress made in this direction.

Control of the Process—This is perhaps the most important single factor in good bonding. In principle, all that is necessary is to follow through the adhesive manufacturer's instructions, supplemented by special knowledge of the components to be bonded and the tooling and equipment used. In practice, however, it is always possible to deviate from the correct path, and special attention should be paid to:

(a) Thorough degreasing.
(b) Strength, temperature and adequate agitation of the pickle bath. The pickle should be given a regular strength check, should have a reliable thermostat control, and should be fairly severely agitated, e.g., by blowing compressed air into it. Especially in large baths there can be a very considerable difference of temperature between the top and the bottom.
(c) Careful washing, but the water must not be above 60 deg. C.
(d) Maintained cleanliness of the parts after pretreatment by having a clean shop and careful handling. Adhesive application soon after pretreatment is a great help.
(e) Adequate and consistent adhesive application.
(f) Adequate temperature and pressure at the glue lines during curing. Extensive use of thermocouples, especially on the first part, and careful tool design are the most important points in this respect. Recording charts should be used as an aid to the inspection department. Where the adhesive is cured above its maximum service temperature, it is important also to ensure that pressure is not removed before the part has been sufficiently cooled.

TABLE 3. Chance-Vought chemical cleaning process for FS-1H magnesium alloy

Preliminary Cleaning
Vapour degrease in trichlorethylene, 2–5 min.
Caustic cleaning 8–12 oz./gal. sodium-hydroxide for 5–15 min. at 63–80 deg. C.
Rinse in tap water for 2 min.
Acid etch 20–24 oz. gal. chromic acid.
1·84 oz./gal. calcium nitrate for 5–15 min. at 52–63 deg. C.
Rinse in condensate water for 2 min.
Final Cleaning
Acid etch in 16 oz./gal. chromic-acid 0·8 oz./gal. sodium-sulphate for 3–12 min. at 52–63 deg. C.
Rinse in condensate water for 2 min.
Dry in air or force-dry for 5 min.

TABLE 4. Typical properties of a bonded honeycomb (Aeroweb)

Density, lb./ft.³	4·0
Shear strength, p.s.i.	230 (long.) 141 (trans.)
Compressive strength, p.s.i. ...	340 (with skin) 262 (without skin)
Elastic modulus, p.s.i....	31,900 (long.) 21,300 (trans.)

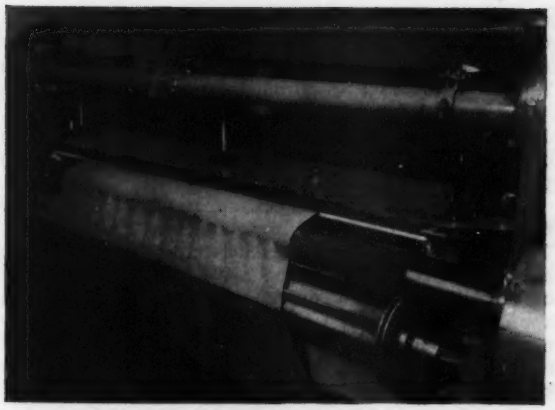


Fig. 3. Textile machine incorporating honeycomb-cored vibrating platform.

Some reliance must be placed on the operators controlling the process, but inspection can also cover most of the ground.

Use of Test Pieces—It is usual to bond lap and peel specimens at the same time as the main components (special provision being made for these on the bonding jig). These form a check on the adequacy of the pretreatment and cure, and give the designer confidence that his required strengths are being achieved.

Although it has not such direct design significance, the peel test is more critical than the lap shear test and is especially suitable as a check on pretreatment. The drum peel test is that normally used in Europe, and Fig. 2 shows such a test being made on a Hounsfield Tensometer.

Since, as mentioned above, the design significance of any particular peel test is doubtful, several different ones have been used, including, for example, the climbing drum peel test in the U.S.A., and pull-tests of various types used by de Havilland in England. Such differences are unfortunate, in preventing direct comparison between the methods of various companies, but for any particular company these various tests may still be of extreme significance in quality control.

Inspection of Bond Appearance—The main points to look for here are that there is some squeeze-out of adhesive all along the edges of the bonded areas and that the colour of the excess adhesive is consistent with an adequate cure. Additionally checks should be made of glueline thickness to see that it is within normal limits.

Destruction Tests—These tests may vary from a complete structural test on the first component to the occasional stripping off of a single stringer. Stripping down of the component gives a good qualitative indication of the adequacy of the whole bonding procedure and especially of the bonding fixture.

Non-destructive Testing—The search continues for suitable non-destructive testing of bonds and some progress is being made. For some years, tapping tests have been used as a means of locating voids using, for example, a

small hammer. Certainly this kind of procedure is yet another check on the bonding, but it is subject rather severely to human error, and it also detects only complete lack of bond, and gives no indication of imperfect bonds.

For honeycomb sandwiches a simple vacuum tester (Fig. 1) may be used. A dial gauge records the lift of the skin due to the application of the vacuum, but again this is purely a detector of voids.

A somewhat more complex apparatus is that under development in the U.S.A. and known as the Stubmeter. This uses a single ultrasonic exciter-detector, and measures the local impedance of the bond. Not only is complete lack of bond detected, but also degrees of poor bond. This appears to be the most promising instrument at present under development.

Honeycomb Sandwich Structures

Metal bonding has led to one particularly interesting development—the honeycomb sandwich structure. The principles of sandwich construction are not new, having been suggested more than 100 years ago. The advent of aluminium honeycomb has made such structures more efficient, cheap and practicable, and thus made this whole field of much greater significance.

It is worth while to review briefly the advantages of honeycomb sandwich structures. In the main, honeycomb sandwich construction has the advantages of structures in which metal-to-metal bonding is used, but it is particularly attractive in having (1) high strength-to-weight ratio (2) high stiffness-to-weight ratio, (3) smooth skin, and (4) simplicity, leading to great economies in design and manufacturing time and thus to low cost. The first three advantages are related to the high stabilising effect of the core on the skins. This means that buckling does not occur until a very high stress, and failure in compression, for example, frequently reaches the 0·2 proof stress of the facing material. So far as the fourth advantage is concerned, economies arise from the fact that a single slab of honeycomb core can replace a large number of stiffeners. Thus the number of parts in the overall structure can be drastically reduced, and the manufacture much simplified, bearing in mind also that a large sandwich panel can be bonded in one operation as described below.

Aluminium honeycomb is probably the best all-round sandwich core at this time because of its strength, durability (complete resistance to fungi, etc.), fairly low cost (down to £3/cu. ft.) and low density (see Table 4).

Cores of as low a density as 1¼ lb./ft.^{3} have been made, compared with an average balsa density, for example, of about 8 lb./ft.^{3} It is true that honeycomb properties are directional, but this is just what is needed for sandwich work (in particular, high strength perpendicular to the faces).

Manufacture of Honeycomb Cores—There are two main methods of manufacturing honeycomb core:

Corrugating Method. In this method foil (usually between 0·001 in. and 0·004 in. thick) is cleaned and corrugated and has adhesive applied to it (preferably only on the areas to be bonded). In this form, it is laid up into blocks, and then cured in an oven. Slices are cut off to requirements on a high-speed bandsaw.

Expansion Method. In this method, staggered stripes of a phenolic adhesive are applied to the foil, which is then stacked flat and cured in a press. After curing, slices are taken off on a bandsaw and expanded to the right density, usually on a special sort of "lazy tongs".

Both have their merits. The expansion method generally assists accurate cutting, simplifies the cutting of profiles and is possibly slightly cheaper, whereas corrugating gives a more consistent product and enables thick slices to be made without difficulty.

Bonding of Honeycomb Sandwiches—The bonding of cores to skins is a very straightforward operation and use is generally made of a film-type adhesive. Pretreatment and general methods of bonding are similar to those described above and similar care must be taken. One advantage, however, when bonding sandwiches is that vacuum pressure only is sufficient to make the bond, though in the case of the edge members some extra pressure should generally be applied. The bonding is, therefore, frequently carried out on a steam-heated, water-cooled vacuum table and the sandwich is laid up on this in the sequence: bottom skin, film of adhesive, core, film of adhesive, top skin. The whole is then covered with a rubber blanket.

Generally, it is desirable to prime the core with a small amount of liquid adhesive in order to give a good fillet. With some adhesives it is also necessary to prime the skins. Liquid epoxy adhesives are also sometimes used for bonding cores to skins. Where large production rates are required, multi-daylight presses may be used.

Current Uses—Extensive use of honeycomb sandwich is being made in new aircraft. In the Convair B.58 Hustler, for example, it is stated that ninety per cent of the skin surface uses honeycomb sandwich construction.

The use of honeycomb sandwich for commercial purposes has naturally lagged somewhat behind that for aircraft, but the potentialities here are very great; one rather specialised application has been that for an oscillating table on a textile machine (Fig. 3). In this case the honeycomb sandwich table weighs about one-tenth that of the cast-iron table which it replaces. The significance here is that this reduction of weight has enabled the machine to be run at about two and a half times the speed achieved with the cast-iron plate. Clearly, the additional trouble involved in re-designing this part has paid very handsome dividends.

In general, one expects that honeycomb sandwich will play an important part in future commercial structures where accelerations are involved, or where the weights of the structures themselves cause a significant portion of the loads on them. The textile table is perhaps an extreme example in the first category, which also includes all forms of surface transport (cars, trains and boats). (In the case of boats, a more significant saving is that of drag due to decreased draught.) A 13-ft. runabout boat has recently been built in the U.K. entirely from honeycomb sandwich, and it has a finished weight of 210 lb. compared with 340 lb. for a plywood boat of the same dimensions. Due to the buoyancy of the sandwich itself, this boat was found to be quite unsinkable, even when filled with water. The Rover gas turbine car (Fig. 4) has a floor consisting of one large honeycomb-cored panel, thus contributing to a very high power-to-weight ratio.

In the second category where the weight of the component itself is an important load, one may include such applications as radar reflectors and bridges.

Fig. 4. The floor of the Rover gas turbine car is one large honeycomb-cored panel.

The author wishes to express his thanks to those other members of the staff of Ciba (A.R.L.) Ltd. who assisted him in the preparation of this article.

TORSIONAL STRENGTH OF WIRE

THE U.S. National Bureau of Standards has recently completed an investigation of the torsional fatigue properties of small-diameter, high-carbon steel wire. From the experimental results, it appears that the behaviour of small-diameter spring wire can be more realistically determined from torsion tests than from the conventional tensile tests now used as a criterion.

The study was conducted on three different types of wire: a cold-drawn music wire, an oil-tempered music wire and a wire fabricated from a special heat of vacuum-melted steel.

Stress vs. cycles-to-cracking curves were derived from the test results. These curves showed, at a nominal shear stress range of 140,000 p.s.i., that the fatigue life of springs coiled from the vacuum-melted wire was about twice that of springs made from the cold-drawn music wire. As the primary difference in the two materials is in the size and number of inclusions each contains, the difference in fatigue life may be attributed chiefly to the greater cleanliness of the vacuum-melted material.

The curve obtained for springs of the oil-tempered wire at the same stress range showed an increase by a factor of five over the cold-drawn wire. Here the difference in the two wires is in their metallurgical structure.

The same stress vs. cycles-to-cracking relationship was determined for the straight-wire specimens of the three different types of wire. Excellent correlation was found in the results of the two test methods, with the spring specimens giving a slightly better performance than the straight wire. This behaviour is ascribed to the beneficial residual stress set up in the springs by the pre-setting operation.

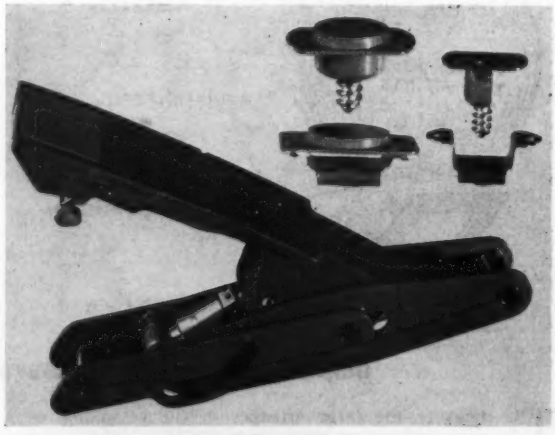
Little correlation was found between the known tensile strength and the torsional fatigue properties of the various wire specimens. In fact, the oil-tempered wire showed the highest resistance to crack initiation, although its tensile strength is the lowest of the three types tested.

In all cases, shot peening increased significantly the fatigue life of the specimens when they were subsequently stressed in torsion. This result is attributed to the highly cold-worked surface layers and the multiplicity of round-bottomed stress raisers or dents caused by the shot peening. These dents along the wire surface tend to distribute the applied stress, thus reducing the effect of any single stress raiser that may have been caused by die marks or imperfections formed during wire fabrication.

SPECIAL-PURPOSE FASTENERS

IN addition to the types of special-purpose fasteners described in the January issue of ENGINEERING MATERIALS AND DESIGN, Aero Controls Ltd. have recently increased their range of fasteners which already have a wide application in industry where high-strength and quick-release properties are required.

The basic principle used in the stud-type tension fastener is a screw thread with a steep helix angle, the shank incorporating steel balls to ensure positive locking and proof against loosening under vibration. These fasteners are available with different head formations and are suitable for flush fitting, the nuts being either the fixed or floating type and the carrier plate designed to suit the particular application. Where the fixing plate of the fastener is located under a panel, the head of the stud is lengthened to accommodate the thicknesses of the panels. In all types the studs are available in standard lengths.



In addition to the tension fasteners, a shear fastener is also available for flush fitting, incorporating the positive self-locking principle used in the stud-type tension fastener.

The new long-reach toggle fastener is capable of taking both a direct tension in the plane of the panel and a load normal to the panel. The fastener is in one single unit which operates within its own depth and incorporates an adjuster for establishing the correct tension.

Type	Nominal Size	Ultimate Shear Load (lb.)	Ultimate Tensile Load (lb.)
Stud-type tension (Fixing holes to order)	Mini-fastener (steel)	—	250
	Standard (steel)	—	600
	Standard (light alloy)	—	450
Stud-type shear (Fixing holes to order)	Size 1 steel (light alloy body)	9,000	750
	Size 2 steel (light alloy body)	1,500	250
	Size 3 steel screw (steel body)	6,000	450
Stud-type unit (Non-separable type for clamping panels together)		Load normal to panel	
Toggle-type panel (To suit flat panels or panels of various radii)	Size 1	100	2,000
	Size 2	100	2,000
	Size 3	100	2,900
	Size 4	100	2,900
	Long-reach	450	4,000

designer's notebook

Square or Rectangular Adjustable Aperture

IN a piece of radiotherapy equipment employing a cobalt radio-isotope as a source of radiation, it was necessary to provide a window in a sphere of shield material (lead) which could be adjusted so that the area undergoing treatment could be varied from a square to a rectangle, and also increased or diminished in size. In order that the field of radiation should be sharply defined, without penumbræ, it was desirable that the sides of the aperture, which had to have considerable thickness, should always be radial with the centre of the sphere. To achieve this, it was necessary to devise a means whereby they should hinge apart from intersecting axes at right angles to each other on the mid-plane of the sphere. Fig. 1 illustrates the nature of the problem to be solved.

The solution provided by Servotec Ltd. is illustrated diagrammatically in Fig. 2. Pivoting about two axes, AA and BB, at right angles and in the same plane as the radiation source are two pairs of stirrups DD and CC, from each of which depend arms carrying four shield blocks of G.E.C. heavy metal, 1, 2, 3 and 4. These blocks constitute the four sides of the window. Each block abuts at one end against the inner face of its adjacent block, but overlaps the end of the block at its other end. To each block is fitted a plate, G, at one end carrying a pin, H, which is a slide fit in an arcuate groove in the adjacent block, thus providing freedom of movement in one direction only. On each of the depending arms are lugs in which are tapped holes to carry two operating screws, E and F, threaded left- and right-hand; these serve to draw together or pull apart the opposite sides of the window.

Although originated for radiotherapy purposes, it would appear that the same principle could be used for optical applications. In such cases, however, the operating screws would have to be offset from the light path and not as shown in Fig. 2.

Fig. 1

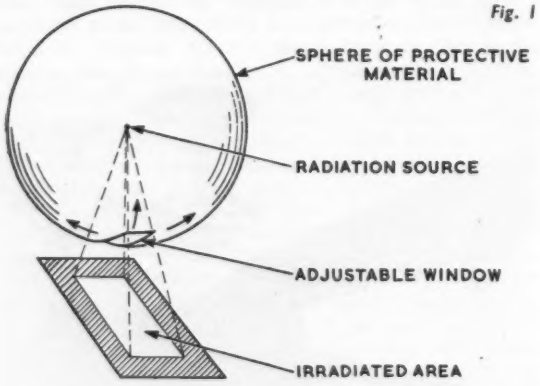
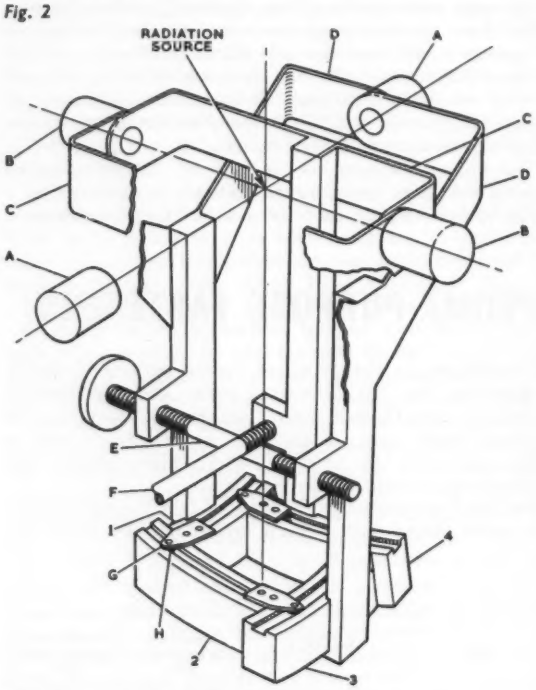
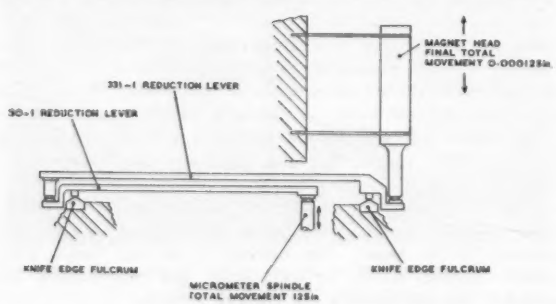


Fig. 2



Displacement Meter Measures to One Millionth of an Inch

TO measure the large changes in the resistance of a specimen of indium antimonide which take place when it is moved in a magnetic field, it was necessary to provide a displacement meter capable of moving a magnet relative to such a specimen through a total range of 0·000125 in. in 5×10^{-6} in. steps. The photograph shows the piece of equipment developed for this purpose by the Services Electronics Research Laboratory and recently displayed at the Physical Society exhibition.



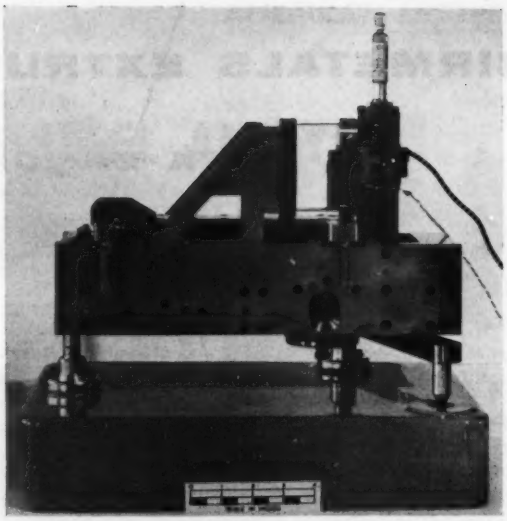
Coarse adjustment of the specimen in relation to the magnet is provided by slides, separate from the sensitive reduction linkage, which enable vertical and horizontal adjustments to be made, followed by locking. The vertical micrometer spindle seen in the photograph provides the vertical coarse adjustment. The advantage of this separate movement of the specimen is that, once the magnet is fitted, the sensitive head need not be disturbed.

The diagram shows the type of reduction linkage devised. It will be seen that domed button contacts are used. These were chosen to reduce friction wear to a minimum. Although a point or line contact system would have been entirely self-compensating, as regards errors due to the arcs described by the moving levers, the maximum error possible with levers of 8 in. total length at the extreme end of

the range is only 0·01 per cent. The points of contact of the buttons and pivots are all in the same straight line when the levers are in the mid-position in order to ensure linear response in the magnet head.

A flat tungsten carbide insert in each lever pivots on a fixed knife edge of the same material, the prevention of end movement being separately achieved by metal straps. The levers are kept in good contact by spring loading. To overcome errors due to load fluctuation, adequate beam strength of the levers was provided by making them 1½ in. deep. The cantilever suspension of the magnet head provides the vertical freedom required without the use of slides.

In order to minimise the effects of temperature variations, invar was used throughout for both frame and levers. Both were built to massive proportions to smooth out local expansions and contractions which, if thin sections had been used, would have resulted in bi-metal strip effects. Large masses of metal tend to smooth out the effects of changes in temperature which might occur due to draughts. A further precaution was taken by providing a transparent plastics cover.

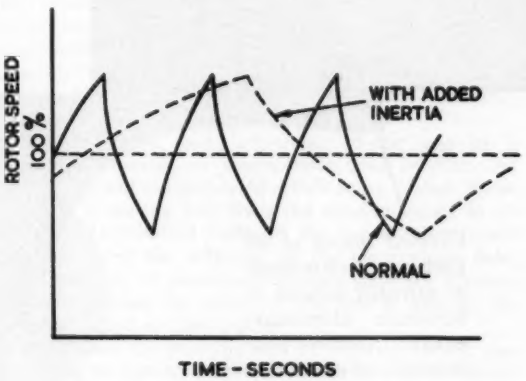


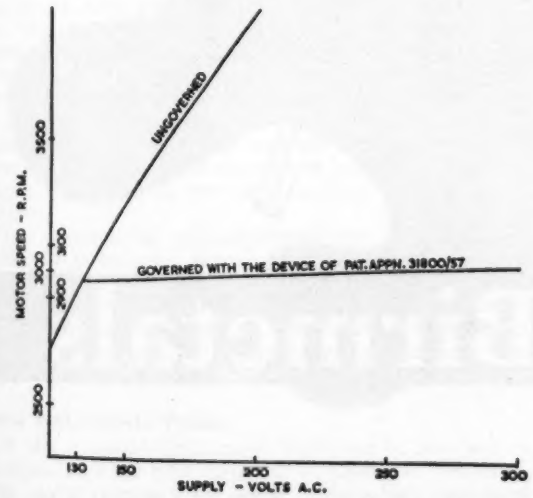
Improved Governor System for Small Electric Motors

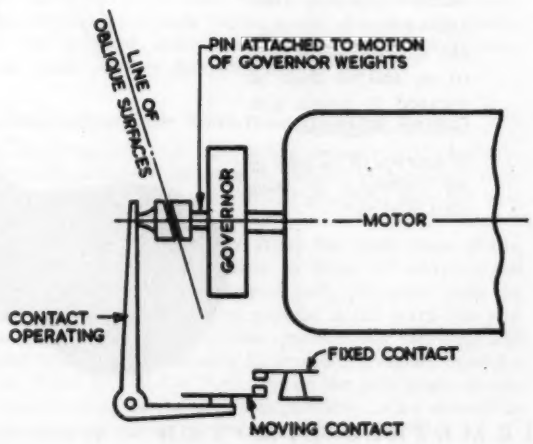
A DEFECTIVE feature of the conventional centrifugal governor-operated contact for the speed control of small electric motors is that outward movement of the weights sufficient to operate the contacts does not occur until a speed above the "governing" speed has been reached. In order that the governor contacts shall then complete their cycle, the speed of rotation must reduce to a value below the "governing" speed. It will be seen that the result is a form of "hunting", or excursions in speed above and below the "governing" speed, at a rate determined by the inertial characteristics of the motor.

A piece of equipment developed by the Signals Research and Development Establishment and exhibited by the N.R.D.C. at the recent Physical Society Exhibition has been developed to overcome this type of limitation. This has been done by adding a vibratory motion to the normal action of the governor contacts. Thus any speed change, however slight, results in an immediate restoring control by the governor contacts.

A proposed motor governor employing the above principle is illustrated. A pin carries an oblique-faced cam which rotates with and on the same axis as the centrifugal governor. This cam is in mechanical contact with a similar oblique surface attached to a bell crank which operates the governor control contacts. The motion so introduced is approximately S.H.M. at a frequency equal to the shaft speed.







EMD 632a for further information

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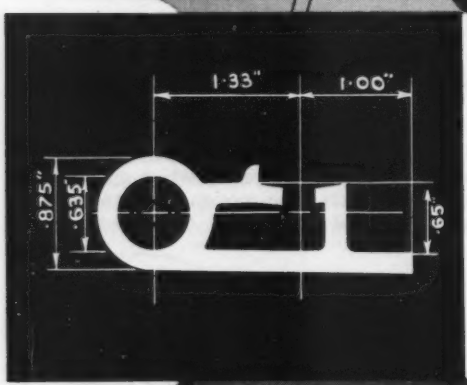

sketch dimensioned section here

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BM241

TWO NEW STAINLESS-STEEL ALLOYS

FROM OUR OWN CORRESPONDENT

SEPARATE announcement of two new stainless-steel alloys has been made by two major U.S. producers.

The first alloy is a new air-hardening, weldable and fully martensitic stainless steel specially developed to eliminate joining problems in highly stressed parts used at temperatures up to 570 deg. C. Essentially, the new alloy is composed of 12 chromium-1¼ per cent nickel and it shows a marked improvement in weldability over 410 stainless and a more uniform structure and higher hardness than 405 stainless. The steel, known as Carpenter 404 alloy, is designed to be free from weld cracking without preheating or post-heating. Weldments can be readily cold worked after stress relieving or annealing. In the annealed condition, the steel is said to be easily blanked, drawn, formed or cold headed. Another advantage is its easy machinability in both the treated and annealed conditions. The alloy is particularly recommended for steam turbine applications.

The second new alloy, known as Armco 22-4-9, is designed to meet the need for a strong, hard material with high resistance to erosion, oxidation and corrosion at temperatures from 480-870 deg. C. Depending on the method of processing, the alloy exhibits a controlled hardness between 300 and 550 Brinell. Being austenitic, and due to its composition and heat treatment, the alloy maintains a relatively high degree of hardness and strength at high temperatures. This is claimed to be a distinct advantage over martensitic and ferritic alloys that suffer a severe decline in mechanical properties over 540 deg. C. For example, with an initial room temperature hardness of 344 Brinell, the material exhibits a hot hardness of 250 Brinell after 1,000 hr. exposure at 590 deg. C.

Pure Quartz Fibre

Continuous mono-filaments of pure fused quartz, which can be twisted into thread and woven into cloth on textile equipment, have been developed by the General Electric Co. Though initial uses appear to be in high-temperature reinforced plastics, other possible future uses include filters, thin insulation in flexible or irregular form and safety devices. The fibres are available from G.E. in short lengths or as continuous thread.

Because of quartz's high strength-to-weight ratio and resistance to heat, use of the fibre in reinforced plastics is expected to increase the potential pay load of space vehicles.

The continuous mono-filaments are approximately 0·0005 in. in diameter. Several hundred of such mono-filaments can be twisted into thread, which in turn can be twisted into yarn and woven into fabric. In addition to high-temperature strength, the quartz has a high degree of purity, low thermal conductivity, an extremely low coefficient of thermal expansion and a high softening point.

New Extensible Paper

A new extensible kraft paper which can be stretched up to 60 per cent has been developed by Cincinnati Industries. The stretch provides the paper with a high degree of formability. Primary uses appear to be in lamination with thermoplastic sheet, providing a strong composite that can be thermoformed into compound curvatures.

The materials range in thickness from a single ply a few thousandths of an inch thick to multi-ply sheets a quarter of an inch thick or more. Most developmental work to date has been done with laminating the paper to high-impact polystyrenes, but a number of other thermoplastics are being evaluated.

Developmental work indicates that forming may be done on mechanical, hydraulic or air pressure presses using male, female or matched dies. Most success has been had by pressure forming using air pressures up to 350 p.s.i. to form the sheet to the contours of a female mould.

Expected applications include packaging automotive parts such as instrument panels or door panels, interior decorative building panels, toys, trays and tote boxes.

Electrostatic Painting with Hand Gun

The advantages of electrostatic spraying, heretofore available only for automatic operation, can now be obtained with a mobile hand gun. Developed by Ransburg Electro-Coatings Corp., the new gun consists of an atomising bell which is incorporated into a lightweight unit specially designed for manual operation.

A special voltage pack, connected to the gun by a flexible cable, creates an electrostatic field between the atomising bell and the grounded article to be coated. Rotation of the atomising bell feeds the coating liquid to its outer edge. Atomisation (without the use of compressed air) occurs under the influence of the electrostatic field, producing a spray of electrically-charged particles. Electrostatic forces attract the spray to the article, and all the spray is deposited on the article.

In many cases the painting rate of the electrostatic gun is equivalent to, and sometimes faster than, a conventional spray gun. Users have reported coating up to six times as many parts per gallon than with conventional spray guns. Other advantages include higher quality finishes, less operation skill required, and reduced spray booth maintenance, as no waste paint is deposited on its walls.

Fluorocarbon for Void-free Quality Parts

A new grade of p.t.f.e. resin is now commercially available, specifically designed for either extremely high-quality void-free mouldings or very thin skived electrical tape for wire wrapping.

Properties of parts made from the new resin grade, called Teflon 7, are the same as those of conventional p.t.f.e. Key to the high quality of parts produced from the new moulding and extrusion powder is the ultra-fine particle size, which results in lower pre-forming pressures and higher uniformity of density throughout complex moulded parts. According to Du Pont, use of the new grade should overcome many of the previous problems often caused by voids in mouldings or pin-hole porosity in thin film.

New Books

Progress in Non-Destructive Testing. *Edited by E. G. Stanford and J. H. Fearon (Heywood, 60s.)*

IT is evident that if materials or finished articles are to serve a useful purpose, all tests to which they may be subjected must be "non-destructive", except the very few in which the specimen is deliberately destroyed to find out how much stress it can withstand.

The term "non-destructive testing", even though it is something of a misnomer, is used to describe a well-defined group of physical phenomena which are applied to testing in such a way that the specimen suffers no physical or chemical change. Some of these phenomena have been in use for years, others are of recent origin and a few, though clearly of importance in the future, are still in an experimental stage.

The present book is a successful attempt to produce, in English, an annual review of progress in various fields of non-destructive testing. The arrival of such a survey has been a hope for the past ten or more years.

In the present volume there are eight chapters, each by a specialist, and dealing with (1) X-rays; (2) shear wave propagation, i.e., ultrasonics; (3) electromagnetic methods, i.e., eddy currents; (4) neutron radiography; (5) medical non-destructive testing; (6) damping capacity; (7) thermal conductivity; and (8) nuclear magnetic resonance.

Evidently 1 and, to some extent, 5 are already well-developed disciplines, whilst 2, 3, 6 and 7 are comparative newcomers, but 4 and 8—though full of promise—are still experimental so far as routine testing is concerned.

The editors and the authors can be warmly complimented on this first stock-taking of non-destructive techniques. The promise of articles on penetrant and magnetic particle testing and the hope that fluorescent X-ray analysis may also find a well-deserved place show how large the whole subject is, and how much matter already awaits discussion in future volumes.

A special mention must be made of medical non-destructive testing. Here, more obviously than anywhere else, the term is restricted to the narrow definition given above, because all medical testing must quite evidently be non-destructive. The field to be covered is, however, unexpectedly large and this is born out by the excellent list of references to literature which appears at the end of each chapter and which, in the case of medicine, totals 109 items. Moreover, there is the promise of more to come.

W.E.S.

A Dictionary of Metallurgy. *By A. D. Merriman, G.C., O.B.E., M.A., D.Sc., C.I.Mech.E., F.R.S.E. (MacDonald & Evans, 126s.)*

This superb volume is beautifully printed and arranged, and while the price will probably be beyond many individuals, the book should be in every technical library. In addition to metallurgical terminology, compositions, physical properties and typical applications of proprietary alloys are included, and in many instances are tabulated for clarity, a comprehensive index of these tables enabling the reader to obtain the information with the minimum of trouble. Where appropriate, diagrams and photographs are used to explain the terms which range over a very wide field covering subjects such as welding, eutectoids, thermopiles and the Steckel mill; these, too, are indexed. By no means least in importance are the tables of common abbreviations and symbols generally used in metallurgy and associated with science, this table being enhanced by a subsidiary list of abbreviations used in foreign technical literature which should be of great value to research workers reading translations of foreign technical papers. Preceding the main dictionary is a table of the physical properties of fifty-nine elements.

R.D.C.

Technology of Columbium (Niobium). *Edited by B. W. Gonser and E. N. Sherwood. (Chapman & Hall, 50s.)*

Diplomatically, the editors have used both the names of the material for the title of this book, which is a useful collection of seventeen papers each written in the style of its individual author.

The papers have been selected to cover the metal from aspects which are either of direct application and interest or which will assist the inquiring metallurgist to further his investigations. The coverage ranges over a review of the properties of the metal, the supply situation, extractive and process metallurgy, electroplating, etc., and then to research, analysis, effect of gases, alloy studies and related subjects.

The design or fabrication engineer thinking of processes and components in niobium would do well to have this book, because the information offered is readable, practical and useful, and includes curves showing the effect of annealing temperatures and periods on physical properties.

R.D.C.

LETTERS TO THE EDITOR

How Can We Teach Design?

Sir,

While Mr. R. M. S. Kay's article, "Industrial Design in Engineering" (February), has ably shown the necessity for a closer liaison between technics, ergonomics and æsthetics, his emphasis seems to be on the professional industrial designer.

Surely, if we as a nation are to sell our products on the world's buyers' market, we must either produce out of the hat many thousands of design specialists and immediately convince all manufacturers of the need for them, or introduce at once the subject of "designing for eye-appeal" into the curriculum of the junior draughtsman and design engineer, for this is the source of more than 99 per cent of our products.

The big problem, of course, is how best such design can be taught. As a science it would be comparatively simple, but it is an art, and one cannot teach art to the man who has no eye for line.

Until some "mode of measure" has been introduced into designing for appearance, we must rely on the industrial designers and consultants, who are too few in number, and on the draughtsman with an eye to line.

John Rollitt

Copmanthorpe,
Yorks.

Sir,

May I correct the reference to consultant designers in your January issue ("News of Industry")? The private exhibition held at the Design Centre was concerned only with the work of *General* Consultant Designers, a specialist group within the Society of Industrial Artists, and not with the work of specialist consultant designer members of the S.I.A.

The General Consultant Designers' Group consists of members whose special interest lies in the direction of design, such as forming design policies for their clients' companies. These members invariably practise in several different categories of industrial design.

The majority of consultant designers within the S.I.A. restrict their activities to a few categories such as engineering design and product design, or packaging design and publicity design. Specialist groups cater for both staff and consultant designers working in these fields, such as the large Engineering Products Group, of which roughly half the members are consultants.

Sunbury-on-Thames, Middx. **L. E. Wingfield**

Engineering Materials and Design

DATA SHEET No. 12

ZIRCONIUM

Properties

Allotropy	α to β transformation temperature 863°C. α is hexagonal close-packed lattice β is body-centred cubic lattice	
Density at 20°C.	6·5 gm./cm.³	(0·235 lb./in.³)
Melting point	1,845°C.	
Specific heat	25–100°C.	6·32 cal./mol./°C.
	α Zr 862°C.	8·03 cal./mol./°C.
	β Zr 862–1,127°C.	7·27 cal./mol./°C.
Thermal conductivity at 50°C.	0·04 cgs. units	
Linear coefficient of thermal expansion	20–100°C.	$5{\cdot}4 \times 10^{-6}$ per °C.
	20–400°C.	$6{\cdot}9 \times 10^{-6}$ per °C.
	20–700°C.	$8{\cdot}9 \times 10^{-6}$ per °C.
Thermal neutron absorption cross-section for natural element	0·18 barns	
Stable isotopes produced at Isotope Division, A.E.R.E.	Zirconium 95, half-life 65 days Zirconium 97, half-life 17 hours	

Improvement in tensile strength by alloying

	Iodide zirc. annealed	Kroll zirc. annealed	1·5% alum.*	7·5% molyb.*
Ultimate tensile strength, p.s.i.	22,400–42,600	42,600–62,700	105,500	134,400
Proof stress, 0·2% offset, p.s.i.	6,720–24,640	22,400–38,100	95,400	—
Elongation, %	24–54	23–40	22	10
Modulus of elasticity, p.s.i.	11·3–13·9 $\times 10^6$	13·6–14·0 $\times 10^6$	—	—
Reduction in area	25–75	27–60	35	40
Hardness, VPN	73–130	120–160	246	280
Charpy impact, ft. lb.	2–7	14–16	—	—

**Graphite melted sponge, hot extruded*

V-notch Charpy impact tests on arc-melted iodide zirconium

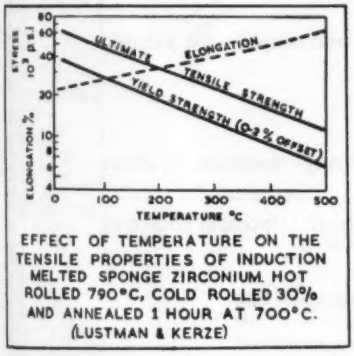
Temp. °C.	—150	—100	0	100	150	170	200	230	325	400
Energy absorbed (ft. lb.)	7	7·5	10	20	40	60	80	90	100	90

Corrosion of crystal bar zirconium (14-day tests, Miller)

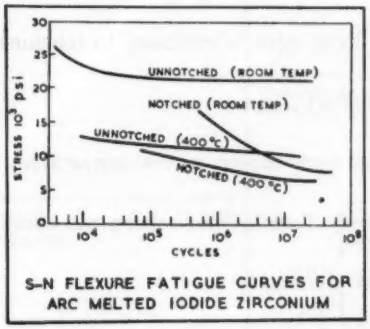
Media	Concentration	Average corrosion rate, mil./year 20°C.	Average corrosion rate, mil./year 100°C.
HCl	5%	No attack	No attack
	Concentrated	0·1	0·2
H_2SO_4	10%	0·2	0·7
	Concentrated	—	Attacked
HNO_3	10%	0·01	0·03
	Concentrated	0·01	0·05
Aqua regia	—	Slow attack	Attacked
HF	—	Rapid attack	—
H_3PO_4	10%	0·02	0·05
	Concentrated	0·04	Attacked
KOH	10%	0·02	No attack
NH_4OH	28%	0·03	Gained weight
Chlorine water	—	Attacked	Embrittled
$FeCl_3$ solution	—	Attacked	Embrittled

REFERENCES

"Zirconium", G. L. Miller (Butterworth).
"Metallurgy of Zirconium", Lustman & Kerze (McGraw-Hill).
"Zirconium and Zirconium Alloys" (American Soc. for Metals).
"Reactor Handbook (Materials)", U.S.A.E.C. (McGraw-Hill).
Information Circular 7830. U.S. Bureau of Mines.
Prelim. Report on Electrical Resistivity of Zirconium, L. A. Cook (W.A.P.D.25).
Fatigue Notch Sensitivity of Zirconium and Zirconium Alloys (W.A.P.D.88).
Fabrication and Mechanical Properties of Ductile Zirconium, E. T. Hayes, Trans. A.S.M. 42:619 (1950).

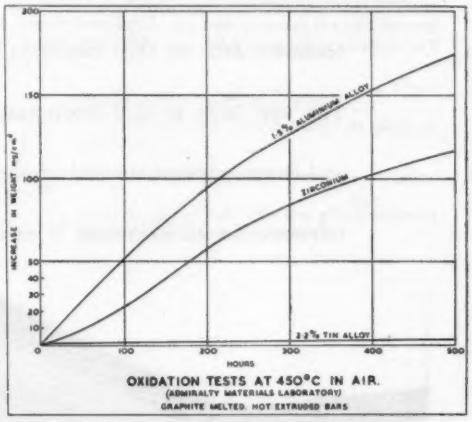


EFFECT OF TEMPERATURE ON THE TENSILE PROPERTIES OF INDUCTION MELTED SPONGE ZIRCONIUM. HOT ROLLED 790°C, COLD ROLLED 30% AND ANNEALED 1 HOUR AT 700°C. (LUSTMAN & KERZE)

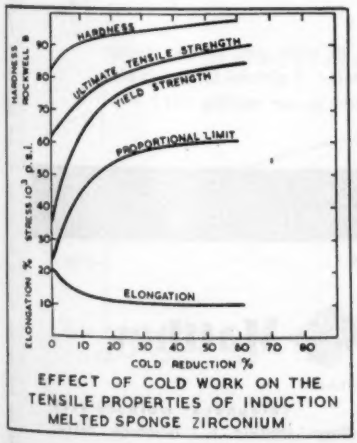


S–N FLEXURE FATIGUE CURVES FOR ARC MELTED IODIDE ZIRCONIUM

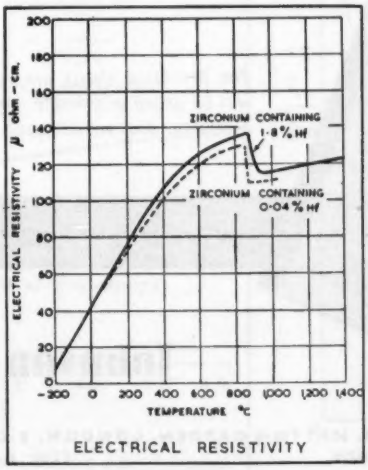
Data sheet by C. Judge, A.Met., A.I.M., Admiralty Materials Laboratory.



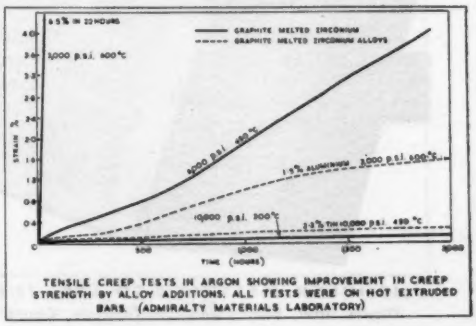
OXIDATION TESTS AT 450°C IN AIR. (ADMIRALTY MATERIALS LABORATORY) GRAPHITE MELTED. HOT EXTRUDED BARS



EFFECT OF COLD WORK ON THE TENSILE PROPERTIES OF INDUCTION MELTED SPONGE ZIRCONIUM



ELECTRICAL RESISTIVITY



TENSILE CREEP TESTS IN ARGON SHOWING IMPROVEMENT IN CREEP STRENGTH BY ALLOY ADDITIONS. ALL TESTS WERE ON HOT EXTRUDED BARS. (ADMIRALTY MATERIALS LABORATORY)

EMD 633 for further information

THE PRINCIPLES AND PRACTICE OF

LOW TEMPERATURE SILVER BRAZING

FOR THE INTEREST AND INFORMATION OF ALL ENGAGED IN METAL JOINTING PRACTICE

The increasing adoption of the low temperature silver brazing technique for jointing ferrous and non-ferrous metals, the wide range of alloys and fluxes now available and the experience gained from their use in many industries have made it necessary to reorganise and amplify the existing technical data on this important subject.

This new series of data sheets covers many aspects of low temperature brazing—selection of alloys and fluxes, applications and operation. Together these sheets will constitute an important source of reference for all interested in metal jointing.

The first data sheets are now in print and further sheets will be issued at monthly intervals. A special binder is also available. May we add your name to our mailing list?

Johnson Matthey

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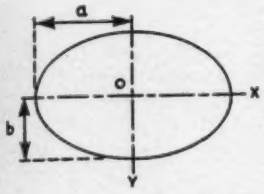
B82

TORSIONAL SHEAR STRESSES

Engineering Materials and Design
DATA SHEET No. 13

The Circle
Maximum shear stress occurs at the circumference and is:

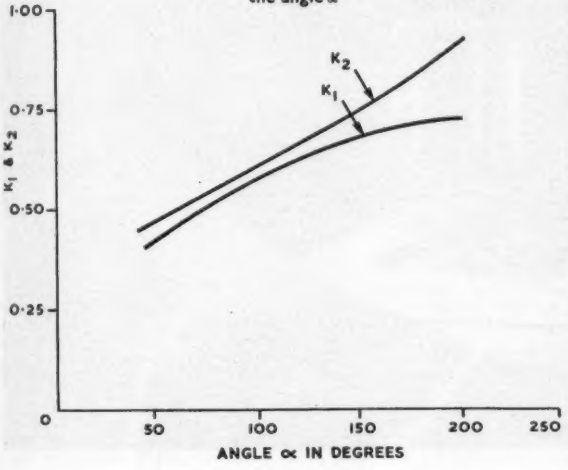
$$f_{s\,max} = \frac{2T}{\pi r^3}$$



The Ellipse
Maximum shear stress occurs at the ends of the minor axis and is:

$$f_{s\,max} = \frac{2T}{\pi ab^2}$$

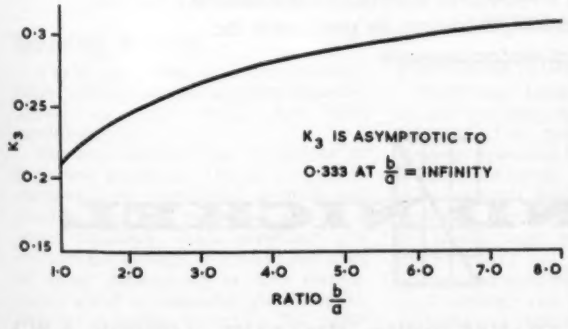
Segment of a Circle
Maximum shear stress at circumference = $K_1 G.r.\theta$
Maximum shear stress at radial sides = $K_2 G.r.\theta$
where G is modulus of rigidity;
θ is the twist per unit length in radians; and
K_1 and K_2 are constants varying with the angle α

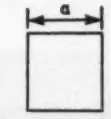


The Rectangle
Maximum shear stress occurs at the mid-point of the long sides, b, and is:

$$f_{s\,max} = \frac{T}{K_3 a^2 b}$$

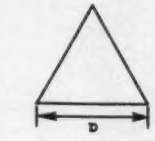
where K_3 is a constant varying with $\frac{b}{a}$.





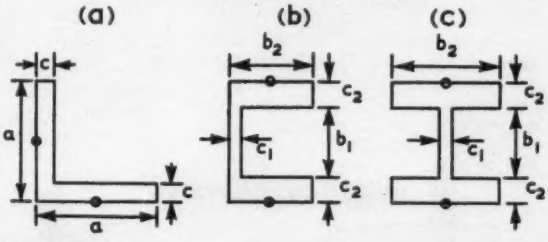
The Square
Maximum shear stress occurs at the middle of the sides and is:

$$f_{s\,max} = \frac{T}{0{\cdot}208a^3}$$



The Equilateral Triangle
Maximum shear stress occurs at the middle of the sides and is:

$$f_{s\,max} = \frac{40T}{a^3\sqrt{3}}$$

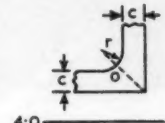


Profile Sections
The torsional rigidity of the section is equal to the sum of the torsional rigidities of the three rectangles. Maximum shear stress occurs at the mid-point of the outside edge of the flange (at the point indicated 0), and is:

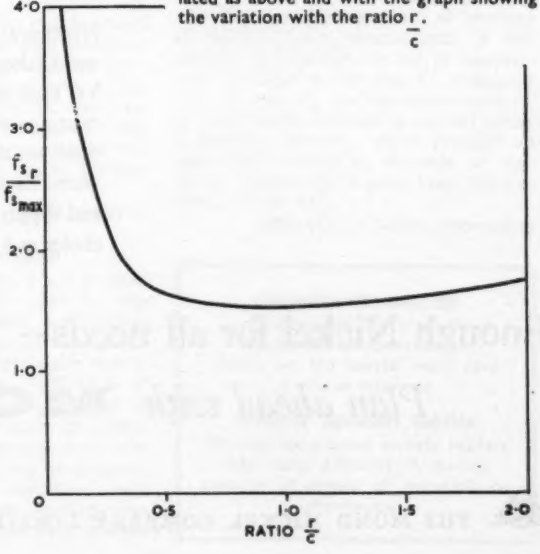
$$f_{s\,max} = \frac{3{\cdot}33\,T\,C_2}{(b_1c_1^3 + 2b_2c_2^3)} \quad \text{for } \frac{b}{c} \text{ ratios between 5·0 and 10·0}$$

$$\text{and } f_{s\,max} = \frac{3{\cdot}0\,T\,C_2}{(b_1c_1^3 + 2b_2c_2^3)} \quad \text{for } \frac{b}{c} \text{ ratios greater than 10·0}$$

For a section of uniform thickness, such as section (a), it is sufficient to calculate the centre-line length, and then to treat the section as a rectangle of this length and width, e.g., section (a) is equivalent to a rectangle (2a–c) × c.



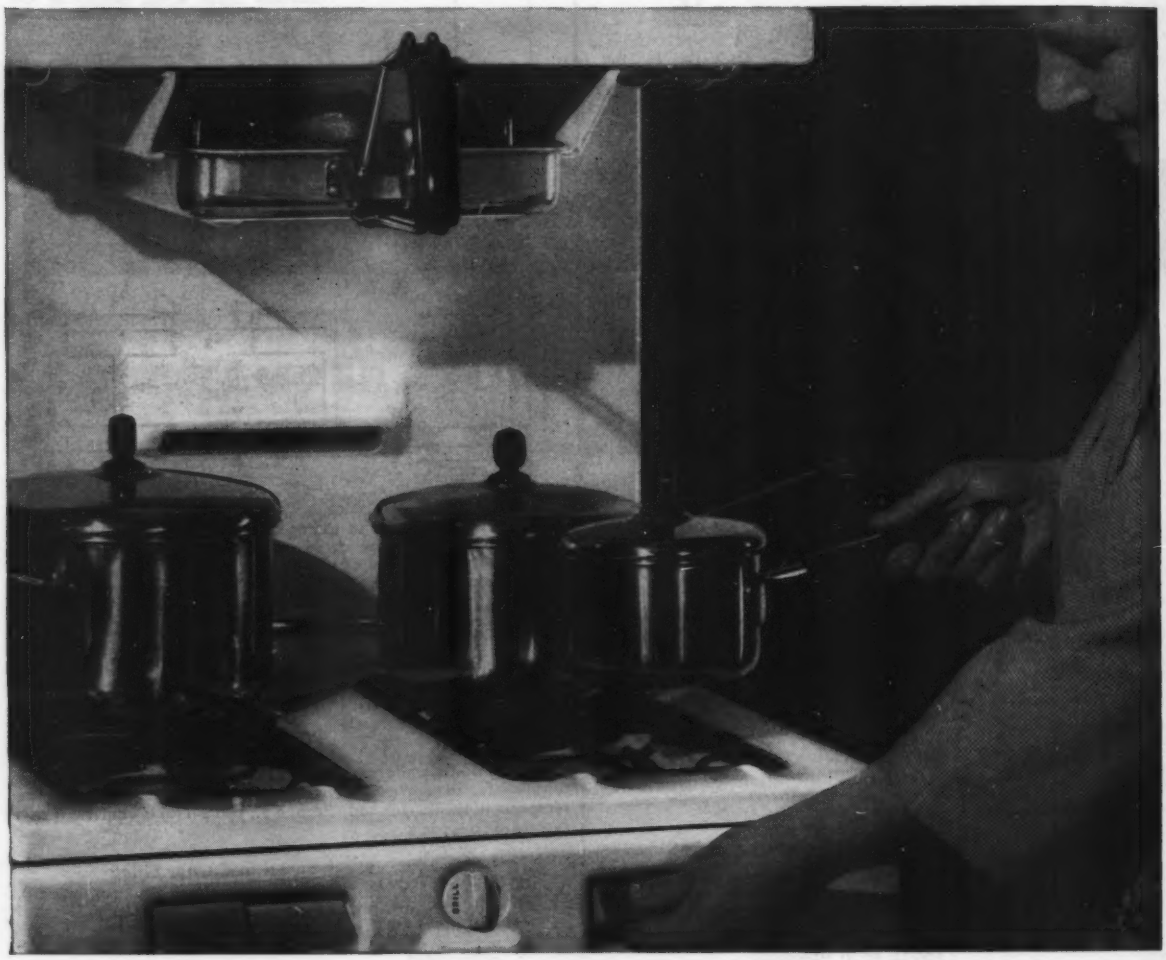
Shear Stress in Corner Fillet
Maximum shear stress occurs at point 0, and is $f_{s\,r}$.
The value is obtained from $f_{s\,max}$, calculated as above and with the graph showing the variation with the ratio $\frac{r}{c}$.



Data Sheet by H. Vincent, B.Sc., A.F.R.Ae.S.

EMD 634 for further information

EVERY PICTURE TELLS A **NICKEL** STORY



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WHAT'S NEW IN MATERIALS & COMPONENTS

Extra-thick Hardboard

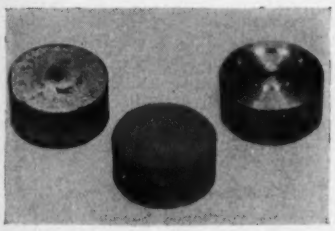
Extra-strong hardboard, ¼ in. thick, is now being manufactured in the U.K. It is said to have great structural strength and load-bearing properties, which recommend it for many uses not previously considered for this material.

Fixed at 24-in. centres, it is claimed to be as strong as the studding behind it, and, at the usual hardboard centres of 12 in. and 16 in., to have breaking loads of 460 lb. and 320 lb. respectively. It is available in standard and oil-tempered grades. Bowater Organisation.

EMD 696 for further information

Hard-facing Process

The new Sprinkle Fuse process for hard-facing with Stellite powder is claimed to offer many advantages where resistance to abrasion, corrosion or heat is necessary, such as on valve seatings, seat rings and discs, pump sealing rings and thrust plates. The process is said to eliminate the need for welding skill and the introduction of automatic heat control, resulting in reduced heating times and the more economic use of hard-facing alloys. Developed in collaboration with Radio Heaters Ltd., the process is said to result in sound deposits of controlled depth, freedom from slag inclusions, blowholes and shrinkage porosity, maximum hardness with good bond and adhesion, well-defined line of junction and very low iron dilution. Photograph shows (*r. to l.*) preparation of steam valve, recess filled with Stellite powder and flux, and, finally, fused deposit after Radyne induction heating. Deloro Stellite Ltd.



EMD 697 for further information

Moulding Material

A new, fast-curing, glass-fibre, mineral-filled polyester dough-moulding material, known as DX 18927, has been announced.

The new material has a number of important properties and is claimed to combine high mechanical strength and excellent electrical properties with good water resistance, track resistance and dimensional stability. Although not quite as strong mechanically as more conventional alkyd or phenolic glass-fibre reinforced moulding materials, DX 18927 components are said to be cheaper to produce and easier to handle and mould, since the material is soft and can be readily preformed by hand without preheating.

Thick sections can be moulded by normal compression methods without the breathing, chilling or long cures which are often necessary with other glass-filled materials. Bakelite Ltd.

EMD 698 for further information

Dust Exclusion Material

A dust-absorbing material, known as Dust Barrier, now on the market, is intended to reduce dust penetration into certain areas. The material is of open-weave and is impregnated with a non-drying adhesive. It does not impede light or ventilation to any appreciable extent. The support framing, on which the dust barrier material is mounted, has been designed to allow for constructions up to 15 ft. wide and of any length. It is said to be easily erected and dismantled and is completely rigid. It allows the use of existing lighting and no additional ventilation is required. It offers a relatively cheap means of eliminating many of the dust problems in manufacturing and finishing processes, storage and packing. Anti-Dust Services Ltd.

EMD 699 for further information

Plastics Finish on Metal

A new technique known as the Plasinter process which, it is claimed, completely overcomes peeling has been developed for bonding polyethylene and other types of plastics to ferrous or non-ferrous metal. It is said to be particularly suitable for wire work, tubular steel assemblies, sheet metals, aluminium ware, brackets, castings, etc. Coatings of p.v.c., p.t.f.e., p.t.f.c.e. and nylon, in addition to polyethylene, will give added strength and resistance to chemical action. The new treatment protects the metals coated from corrosion; they are then non-toxic and the coatings themselves will withstand sterilisation in boiling water. Good electrical insulation properties, reduction of noise and increased hygiene with reduced maintenance are some of the advantages claimed. Darlaston Galvanised Holloware Co Ltd.

EMD 700 for further information

High-temperature Grease

Mobiltempt Grease No. 1 is a product of the non-soap type to cater for the lubrication of plain and anti-friction bearings operating in the 120-260 deg. C. temperature range. Makers claim that it does not melt under the application of heat and that it has no drop point in the normal sense of the term. Its consistency is said not to change materially under conditions of working or temperature cycling, and will therefore resist dripping and leakage from bearings even when serving under arduous duty or high-temperature conditions. The grease is also said to be satisfactory for lower temperatures, though there may be some difficulty in obtaining satisfactory lubrication in close tolerance bearings.

It is claimed to offer excellent protection against rusting and corrosion. Mobil Oil Co. Ltd.

EMD 701 for further information

High-impact Thermoplastic Sheet

The outstanding feature of Fromo-PLAS N, and one which the manufacturers claim gives it superiority over almost all rigid thermoplastic sheeting, is its very high impact strength and resistance to indentation. This is said to be ten to fifteen times that of high-impact polystyrene and rigid p.v.c. The sheeting is also claimed to have excellent ageing and dimensional stability, and to be resistant to grease, petrol and hydrocarbon oils and most acids, alkalis and solvents. Other claims are that it is non-inflammable, has good dielectric properties, negligible moisture absorption, and it can be easily cut, machined, drilled or punched and responds well to forming by the usual vacuum and other normal processes.

Standard thicknesses are 0·020 in., 1/32 in., 3/64 in. and 1/16 in., but thicknesses of ¼ in. up to 1 in. can be made in small-size panels. Seven standard colours are available. Wallington, Weston & Co. Ltd.

EMD 702 for further information

Terylene Power Cable

Varnished Terylene in the form of a woven tape has been introduced as a new type of insulation for use in power cables for electrical supply purposes. The product is non-hygroscopic and has good electrical properties capable of working at high-operating temperatures. It will operate continuously in air at temperatures as high as 130 deg. C., compared with 80 deg. C. for varnished cambric. A considerable increase in current rating is therefore possible, which provides an appreciable saving in the size of conductor required for a given load. Siemens Edison Swan Ltd.

EMD 703 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

Cobalt Platinum Magnetic Alloy

Platinax II is a recent development which, after a special heat treatment, is claimed to be one of the most powerful permanent magnetic materials known. Unlike most base metal magnetic alloys which are relatively brittle, this new alloy is said to be comparatively workable before heat treatment and can be machined, rolled or drawn without difficulty. It therefore lends itself to the manufacture of magnets of complicated shape or extremely small size, whose production might not otherwise be practicable.

After heat treatment by a special process, a remanence of about 6,400 gauss, a coercive force of 4,800 oersteds and a BH_{max} of $9{\cdot}2 \times 10^6$ gauss-oersteds are obtainable. It can be used at service temperatures of up to 100 deg. C., but the magnets should be stabilised after magnetisation by heating them to this temperature for a short period. Johnson, Matthey & Co. Ltd.

EMD 704 for further information

High-vacuum Pumps

A new range of high-vacuum pumps is now being marketed which is claimed to give vibration-free, silent running and an exceptionally low ultimate. The

single-stage high-vacuum rotary piston pump (shown in the illustration) is in 2, 4, 8 and 12 ft.³/min. capacity with an ultimate vacuum of less than 0·005 mm. Hg. The double-stage model is in 2, 4 and 6 ft.³/min. capacity with an ultimate vacuum of less than 0·0002 mm. Hg. The design is said to permit higher pumping speeds at 100 microns and the pressure rise is less than 0·5 mm. Hg. with maximum ballast. Oil changes are reduced to a minimum because of the oil circulation filter system. Genevac Ltd.

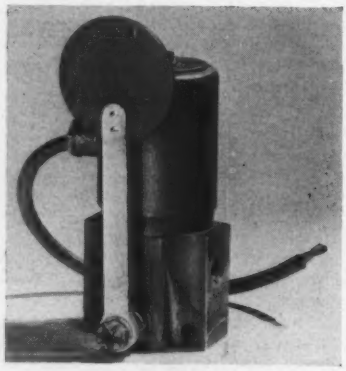
EMD 705 for further information

Seal-less Pump

In the Vanton pump for corrosive chemicals, abrasive slurries, foodstuffs and gases the need for stuffing boxes, packing glands or mechanical shaft seals has been eliminated. The fluid is confined to a channel formed by the outer surface of the flexible liner and the pump body block. Pumping is accomplished by a rotor mounted on an eccentric shaft which rotates within the liner, creating a progressive squeegee action on the fluid trapped between liner and block. The manufacturers state that the gentle pumping action prevents churning or foaming of the fluid, thus preventing excessive settling out of suspensions. The only wearing part is the low-cost flexible liner which can be easily replaced. V. A. Howe & Co. Ltd.

EMD 706 for further information

Hand-start Valve



The new valve type YF/R has been designed for use with automatic protection switches or panels in order to shut down an engine or gas turbine in the event of abnormal operating conditions.

The valve is energised to open so that in the event of electricity failure the engine will be stopped automatically—a particular advantage when applied to the protection of generating sets—but it is fitted with a manual lever which holds the valve open mechanically during the starting operation and is returned to the automatic position by hand when the protection equipment is brought into circuit. The valve is then held open electrically and is thus free to cut off immediately it is de-energised by the protective equipment under fault conditions. It has a straight-through ¼-in. ported body, and may be used to cut off an engine fuel supply or for the control of hydraulically-operated governors. Teddington Industrial Equipment Ltd.

EMD 707 for further information

Check Valves

A new range of check valves developed primarily for high-pressure oil hydraulic applications but also suitable for other oil systems, such as lubrication installations, is announced. The valves, which have hexagon bodies with external threads ⅜ B.S.P. to 1¼ B.S.P. at each end, can be screwed direct into units, thus eliminating intermediate pipes and fittings and any need for supports for the valves. The overall length with fittings is less than that of valves with externally-threaded connections, thus saving space. The valves can be used either as supplied, as check valves, or they can be fitted with an integral by-pass orifice permitting restricted return flow. Hydraulic Components Co.

EMD 708 for further information

Compact Control Relays

A new range of industrial control relays, covering contact arrangements for up to ten circuits, is now available. Although of compact design, these relays are of heavy-duty industrial construction and are suitable for automation control systems and other industrial machinery control applications where duty capabilities are in excess of the most severe category in B.S. 775:1956. All models are rated for 600 volts a.c. duty with 10 amp. current-carrying capacity. All mounting hole dimensions are standardised and terminals are provided with positive pressure wire connections for fast wiring, accessible from the front. The coils are moulded for long life and reduction of moisture absorption. Square D Ltd.

EMD 709 for further information

Air Filters

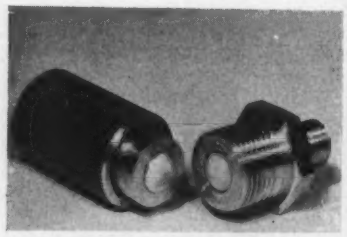
Two new air filters have recently become available. Known as types V4 and V5, they are made up of glass-fibre tissue in a corrugated multi-layer form. The special composition of the glass fibres ensures high resistance to attack by most chemicals. The filter medium will not felt in humid conditions and, because it contains no organic fibres, has little fire risk.

These filters, which need no maintenance, are claimed to cost less than filters of similar type. Because of their low resistance, only low fan horsepower is required, thus affording low operating costs. Both filters are available in a wide range of thicknesses and sizes. Fibreglass Ltd.

EMD 710 for further information

Self-sealing Couplings

Though developed primarily for use with breathing apparatus, a range of low-pressure self-sealing couplings which is now available appears to have many applications in other fields.



The example illustrated is the light alloy standard ¼-in. B.S.P. version with a ¼-in. bore hose adaptor at one end. The retaining union nut is able to slide back along the hose for easy cleaning. On unscrewing the union nut, the two parts of the coupling are separated, enabling each spring-loaded plastics ball to seat and seal each part of the coupling. The two sealing parts of the coupling are resin-bonded assemblies and are individually pressure-tested. Thus, in the event of damage, they are expendable. Other sizes and end fittings are also available. Spembly Ltd.

EMD 711 for further information

Submersible Motor

The new Clam-seal motor has been developed to operate in sand-laden water. Its design precludes the possibility of damage by abrasion to the bearings, and its performance is said to be unaffected by hard or aggressive water in the boreholes.

In this motor a barrier has been created between the borehole water and the motor interior. This function is performed by a radial seal, spring-loaded to operate against a matching stainless-steel face. The interior of the motor is filled with a special low-viscosity oil, maintained at constant pressure by a spring-loaded neoprene reservoir formed in the base. Since the motor is filled and sealed during manufacture, no priming on site is said to be required. Sumo Pumps Ltd.

EMD 712 for further information

High-pressure Flowmeters

A range of flowmeters, suitable for use with a wide variety of fluids, has recently been developed. Available in a range of from 0·5-300 gal./min., they are said to be suitable for the majority of fluids and oils, liquid foods, chemicals, water, kerosene, etc. They are normally supplied calibrated to their own indicators and may be portable or panel-mounted.

The metering unit consists of a main body in which is housed a tapered sliding plug held in the closed position in a sharp-edged orifice by a main control spring. Fluid passing through the meter overcomes the spring force, thus displacing the plug as a function of flow. Linearity is achieved with a suitable combination of initial spring load, spring rate and plug taper. Movement of the plug is transmitted to the indicator unit by means of a potentiometer, through a direct-current balanced bridge network.

The electrical supply is self-contained, power being obtained from two 1·5-volt dry cells. Gloster Aircraft Co. Ltd.

EMD 713 for further information

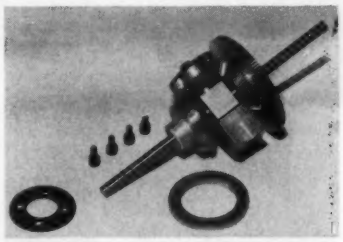
Miniature Transducer

The pressure transducer NT4-317, which is now being made in this country under licence, is claimed to present a great advance in accuracy and miniaturisation techniques. It will function continuously without damage at any temperature between −210 deg. C. and +340 deg. C., and will withstand static accelerations up to 100 g. in any direction. It is said to be particularly suitable for use in the field of nuclear power instrumentation (as a helium leak detector, for example). Because of its small size, the unit is said to be of special value in flight testing of guided missiles. Solartron Electronic Group Ltd.

EMD 714 for further information

Bevel Gear Differentials

A bevel gear type of differential with interchangeable end gears is now available. The bevel gears are mounted on a $\frac{3}{16}$-in. dia. shaft by ball bearings and have accurately machined hubs on which selected end gears can be clamped by means of detachable plates. A wide selection of end gears is available in 48, 64 and 96 D.P. Complete differential kits will also be supplied; these include the differential, two shaft hangers fitted with



needle roller bearings and six pairs of end gears in an instrument case providing a location for every part. Shaft adaptors to $\frac{1}{4}$-in. and $\frac{1}{2}$-in. dia. shafts are supplied in the kits. Pioneer Designs Ltd.

EMD 715 for further information

New Publications and Technical Literature

British Resin Products Ltd.: Technical Note No. P202, giving details of chemical resistance of Cellobond polyester resins, laminates and casts.

EMD 716

Brook Motors Ltd.: Brochure of various types of electrical control gear and their maintenance.

EMD 717

Burtonwood Engineering Co.: New catalogue dealing with the company's range of oil seals, O-rings, mouldings, etc.

EMD 718

Cambridge Instrument Co.: Folder dealing with range of indicators, recorders and controllers for use with automatic gas analysers of the thermal conductivity type.

EMD 719

Cape Asbestos Co.: 24-page brochure of specification details of Rocksil products for various marine uses.

EMD 720

Cement & Concrete Assoc.: Booklet on the design of right concrete slab bridges for abnormal loading.

EMD 721

Dowding & Doll Ltd.: 12-page brochure describing the Dowding H.7 universal hobber.

EMD 722

Dunlop Rubber Co.: Brochure giving the story of design and development behind the Dunlop disc brake.

EMD 723

Helliwells Ltd.: Specification and technical data for straight and manipulated electrically-welded tubes.

EMD 724

Isopad Ltd.: Brochure on Isomantles—industrial electric surface heaters for vessels, pipelines, valves, instruments, etc.

EMD 725

I.C.I. Ltd.: Attractive colour brochure describing the properties and applications of isocyanates. Also booklet dealing with butadiene copolymer resins for rubber reinforcement.

EMD 726

Johnson, Matthey & Co.: Second edition of *Noble Metal Thermocouples* giving survey of their development, applications and methods of calibration.

EMD 727

Geo. Kent Ltd.: Paper dealing with the principles, construction and performance of primary elements for temperature measurement.

EMD 728

Londex Ltd.: Booklet of data on range of electrical remote-control equipment, including recent additions.

EMD 729

Archibald Low & Sons Ltd.: Brochure dealing with Alaflor extruded aluminium gratings and treads.

EMD 730

Mond Nickel Co.: New edition of *Atlas of Isothermal-Transformation Diagrams on Nickel Steels;* also includes supplementary information in the form of continuous-cooling transformation diagrams.

EMD 731

Nat. Council for Technological Awards: List of 77 courses recognised by the council as leading to the Diploma in Technology.

EMD 732

Palmer Aero Products Ltd.: Booklet dealing with X-ray and gamma-ray non-destructive testing methods for materials and assemblies.

EMD 733

Parvalux Ltd.: Latest catalogue of f.h.p. motors and gear units.

EMD 734

Geo. Salter & Co. Ltd.: Brochure illustrating range of applications of crane weighers.

EMD 735

Sperry Gyroscope Ltd.: Catalogue describing specialised components developed for various projects, but which have other potential applications.

EMD 736

EMD 637 for further information

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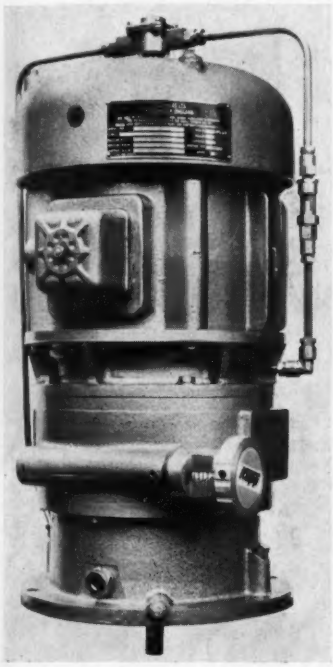
Variable Speed Gear

A modified version of the Kopp variator is now available and has been specially designed for vertical mounting. Previously, because of the splash method



of lubrication, the standard model has only been suitable for mounting horizontally. The new unit is provided with a separate oil sump casting located on the lower flange of the variator. Oil seals are eliminated on the lower shaft by the incorporation of a labyrinth and flinger arrangement which is claimed not to deteriorate in service or allow any oil to leak down the shaft.

Oil is circulated from the sump into the upper bearings of the variator by means of a Suddo pump mounted over and driven by the upper shaft of the electric motor, thus providing full lubrication for the working parts, as oil passes through the unit back to the sump. Size is at present limited to between ¼ h.p. and 5 h.p. with standard stepless speed variation over a 9:1 output speed range. Allspeeds Ltd.

EMD 737 for further information

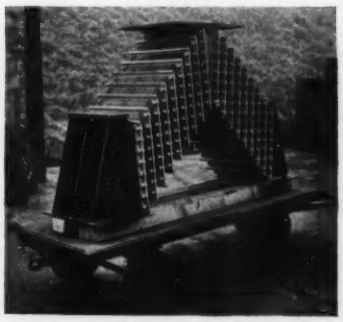
Self-cleaning Filter

Micom filters are claimed to be a new conception in filter design for closed-circuit lubricating oil systems, for service on I.C. engines, power generating and transmission plant, machine tools and any equipment utilising the continuous circulation of lubricating oil under pressure. The filters combine a self-cleaning, plate-type element with a paper element, using to full advantage the best features of paper as a filtering medium. The defined mesh and paper elements are arranged for parallel filtration, thus ensuring, it is said, high efficiency and longer working life for the paper. The paper element cannot be damaged through choking, and full protection to the plant is ensured at all times by the self-cleaning element. All filtered oil passes direct to the clean side of the system, giving maximum protection where it is most needed. Also incorporated is a magnetic element for protection from ferrous particles. The filters are supplied in a range for flows up to 6,750 gal./hr. and in defined meshes from 0·001 in. to 0·003 in. Auto-Klean Strainers Ltd.

EMD 738 for further information

Rubber Fender-buffer

The Raykin rubber fender-buffer, which has previously been manufactured in the U.S.A., is now available in this country. Primarily designed for the protection of harbour installations, it offers a variety of industrial uses where all-angle cushioning action is required. The buffer consists essentially of a V-type arrangement of a series of sandwiches, i.e., a specially-developed natural rubber compound bonded to steel plates. It is claimed to have no parts that can get stuck or jammed, and requires a minimum of service, as all component parts are virtually unaffected by corrosion,

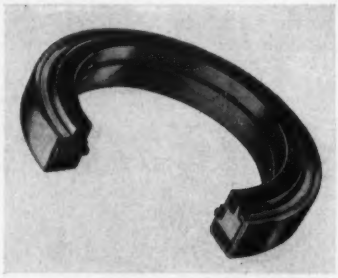


rotting or ageing. The buffer is made according to requirements, with a deflection of from 3 in. to 18 in. Energy absorbed can be run from 5,000 ft. lb. to 104,000 ft. lb. Andre Rubber Co. Ltd.

EMD 739 for further information

Oil Seals

Of recent introduction are two new ranges of Impax oil seals, i.e., the BA type and the RO type. Both kinds are claimed to seal most liquids and gases at very high pressures, speeds, and temperatures, the high pressures being accommodated by an ingenious method of pressure balancing. The main difference between the two types is the overall dimensions, the BA type being of comparatively small width but requiring up to approx. ¼ in. on either side of the shaft, and the RO type being from 1¼ in. to 2½ in. long depending on the shaft size, but requiring only about ⅛ in. on either side of the shaft. Both are normally supplied with bronze rubbing faces for use where there is ample lubrication, but



can be supplied with faces made of a special material where lubrication is sparse. Chas. Weston & Co. Ltd.

EMD 740 for further information

Oil Filter

Featured for the first time at an exhibition is the Micro-Pak by-pass oil filter, which is designed to remove ultra-fine peptised carbonaceous matter from engine lubricating oil, thereby ensuring that the oil maintains its lubricating function. This model is particularly suitable where detergent oils have to be employed. It leaves the full-flow filter free to deal instantly with coarser abrasive impurities. The Micro-Pak is not cleanable, but elements are said to be moderately priced and long-lifed. Stream-Line Filters Ltd.

EMD 741 for further information

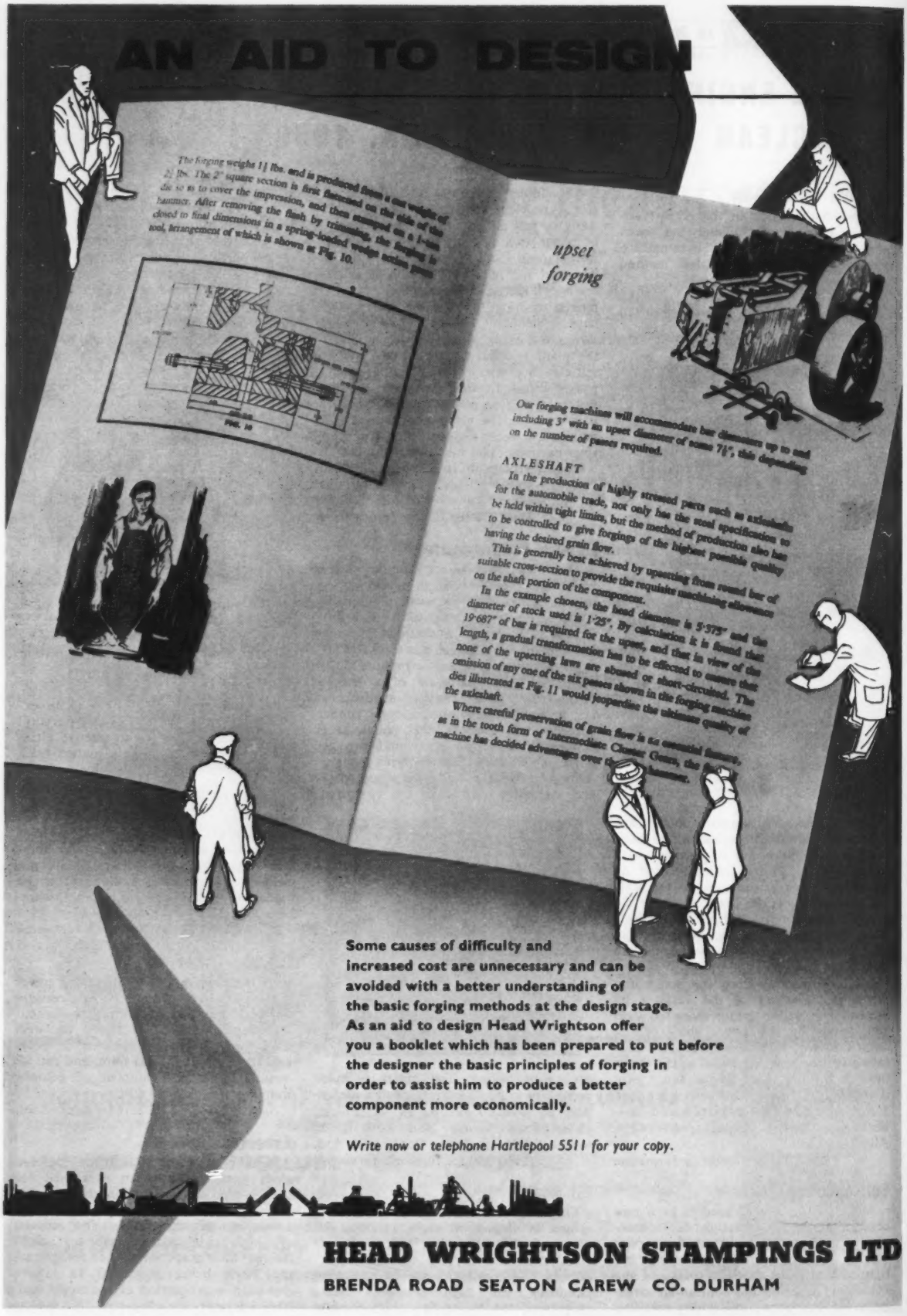
Cooling Tower

A small induced-draught cooling tower is claimed to be of entirely new conception, and has been developed to combat the corrosion problem found on steel shell towers. It is constructed of polyester resin-bonded glass fibre, and can be manufactured in a number of colours. Film Cooling Towers Ltd.

EMD 742 for further information

Asbestos Cloth

A new range of Lascarflon proofed cloth jointings has been developed for use on pipelines, inspection covers, manholes and other equipment in service with corrosive and strong acids. They consist of high-grade woven asbestos cloth treated with a special p.t.f.e. compound, the cloth being processed to ensure thorough impregnation of the compound. The jointings are designed for use at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pressures up to 200 p.s.i. and temperatures up to 350 deg. C. They are supplied in the form of sheeting, tape or ready-cut joints in any required shape or size. Beldam Asbestos Co. Ltd.

EMD 743 for further information

Disc Brake

The Twiflex disc brake is being offered for pneumatic, hydraulic, electro-mechanical and mechanical operation. The hydraulic industrial disc brake employs the Dunlop caliper unit, which can also be used for clutch application. The brake offers many advantages over the conventional drum-type brake, including freedom from fade, ease of maintenance, automatic adjustment for wear and consistent braking under all conditions. It is claimed to be particularly suitable where high braking torques are required in relatively small spaces. Twiflex Couplings Ltd.

EMD 744 for further information

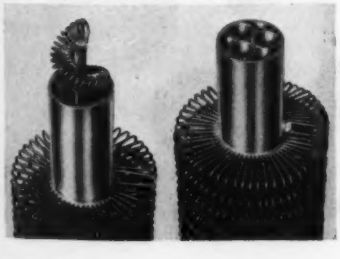
Engine Bearings

Being shown for the first time are soft bronze and tri-metal plain bearings, which are orthodox bearings designed for maximum performance and to last the life of the engine with normal relining. The soft bronze type consists of an outer steel shell, lined with soft bronze, plated with lead. The tri-metal bearing is of similar construction with a thin overlay of white metal. It is claimed that the soft bronze forms a bond of the strongest type which will not yield under any conditions of service. The white metal employed bonds extremely well to the soft bronze, achieved by the special lining methods used by the manufacturer. Hoyt Metal Co.

EMD 745 for further information

Wire-wound Heat Exchanger

In the Clayton-Still tube the extended surface consists of a continuous wire wound in elongated loops which are each firmly bonded to the basic tube in a helical formation. Two special tubes have been developed with the surface extended also within the bore, for special applications such as oil cooling or heating where the poor heat-transfer properties of the fluid cause a high resistance to heat flow. One of these has an insert of normal wire loops which, if required, can be firmly soldered to the tube, while the other, particularly useful when very dirty liquids are involved, has three small-diameter plain tubes inserted and soldered in the bore. Clayton Dewandre Co. Ltd.



EMD 746 for further information

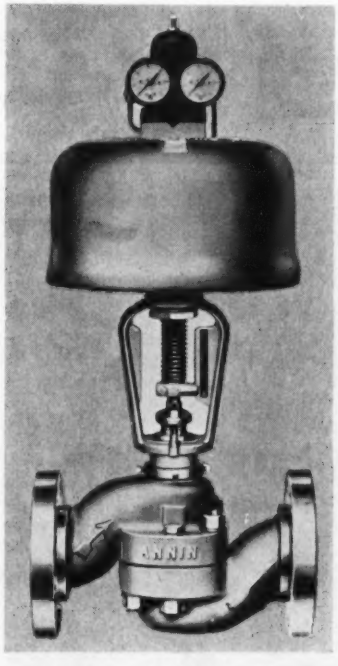
Bronze-welding

A notable step forward in the technique of jointing cast iron by bronze-welding is claimed for the Sifbronze process 101. This process comprises a new filler rod 101 and a new tinning flux which has been specially developed for cast iron, and it is claimed to produce joints infinitely superior to anything previously obtained in this field. Sluggishness of flow across the joint face has been completely eliminated and a far greater degree of penetration of bronze into the parent metal is said to have eliminated "peeling" of joints. Suffolk Iron Foundry Ltd.

EMD 747 for further information

Control Valve

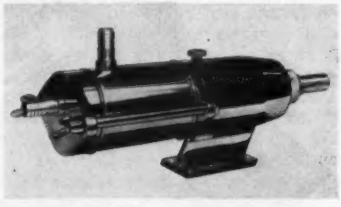
Though produced in the U.S.A. in the past, the Annin Domotor control valve is now being manufactured in this country for the first time. Said to have established itself as an outstanding unit for the control of hot, cold, erosive, corrosive or viscous liquids, the valve has as its basic form a globe body designed to provide for conversion into straight-through, angle or three-way forms with a minimum of parts. The valve is of split design and consists of a body and adapter, thus providing a single-seat design which retains an internal contour of the same area as the relating pipe size. Valve plugs are contoured to provide either linear, percentage or semi-throttle characteristics. Audley Engineering Co. Ltd.



EMD 748 for further information

Small Pump Unit

A new pumping unit which was primarily developed for use on artificial heart machines is now available for light industrial or laboratory operation. For its initial purpose, it was designed for dismantling without tools and the pump section is autoclaved in one piece. This is effected by separating the pump from the driving mechanism to form a pump cartridge, which can be attached to the drive by a pin through the driving shaft.



The principle of the pump embodies a helical stainless-steel rotor revolving in a stator of resilient material. The rotary motion of the rotor in the fixed stator moves a seal continuously through the stator at uniform velocity to positive flow. As the pumping action is produced by rotary motion, the flow rate is proportional to the speed of rotation, which makes calibration of the pump simple. The unit has possible application to research or pilot plants where liquids may be easily damaged and the utmost hygiene is required. Mono Pumps Ltd.

EMD 749 for further information

Mechanical Lubricator

The new Ionic mechanical lubricator uses a two-diameter plunger to give very low-pressure metering and final high-pressure delivery. The larger diameter has a spill-scroll to give fine control of the oil passing to the delivery valve, which is visible and has a tell-tale to indicate correct functioning of the metering section of the pump. Control is claimed to be so accurate that the unit can run at a higher speed than is usual and still deliver small amounts of oil, thus lessening the need for reduction gear, ratchet drives, etc. The small-diameter section is made of nylon. The Ionic is made in a complete range from 2-28 plungers per unit. Loxhams Engineering Works Ltd.

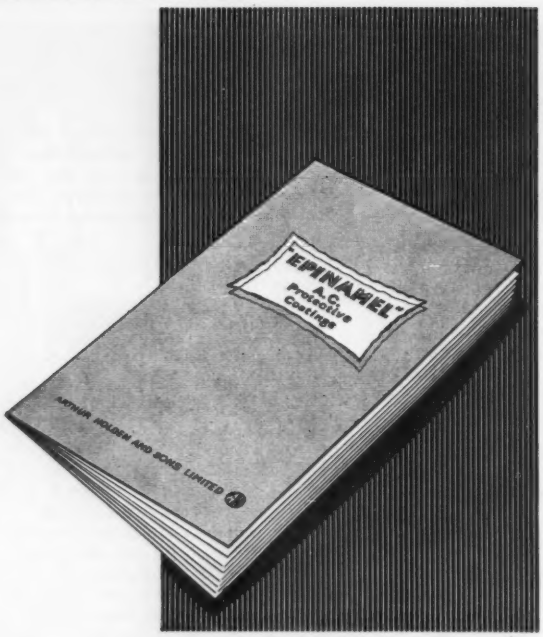
EMD 750 for further information

Stainless Pipe Fittings

A production technique has been developed whereby it is possible to manufacture cast stainless-steel flanges and pipe fittings with properties guaranteed to be equivalent to wrought flanges and fittings. In addition to normal applications, these Paralloy Forging Quality components (as they are called) have been used extensively at service temperatures as low as −200 deg. C. They are at present made in nominal pipe diameters up to 24 in., and it is claimed that they have been accepted by leading chemical plant and refinery operators in Europe and the U.S.A. as interchangeable with their wrought counterparts. A.P.V.-Paramount Ltd.

EMD 751 for further information

EMD 639 for further information



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EMD 640 for further information

News of Industry

A translation service of foreign technical Press articles has been introduced by the **Iron and Steel Institute,** in collaboration with several large companies and the British Iron and Steel Research Association. An English version of an article will be provided at a fraction of the cost if at least two other requests are received. If no others are received, the charge will be higher.

Four lectures dealing with "The Critical Approach to the Design of Machines and Components" were given during February at the **University of Nottingham.** They were the first of a series to be given biennially in memory of Prof. C. H. Bulleid, who occupied the chair of engineering at the university from 1912 until his death in 1956.

A new chair of nuclear science and technology has been established at the **Royal Naval College,** Greenwich. Existing plans provide for courses for design specialists, technical officers and commanding officers.

An information centre has been opened at the London office of the **U.K. Atomic Energy Authority.** Members of the public, commercial firms and other organisations may consult published unclassified material and seek advice on sources of information on atomic energy matters in the U.K.

The death has been reported from Paris of **Dr. Marcel Ballay,** president and managing director of the Centre d'Information du Nickel. During his life Dr. Ballay contributed extensively both in research and teaching to many aspects of metallurgy.

Aero Controls Ltd. announce the appointment of **Mr. W. H. Haydon-Soutar** as chief engineer.

A large extension to the laboratories of **Wakefield-Dick** has been opened at Hayes, Middlesex. Volume of research and development of industrial lubrication methods has increased by 300 per cent in the last ten years, says an announcement by the group.

Shell Chemical Co. announce that they are now proceeding with the construction of large-scale polyolefin manufacturing facilities which will be installed at the works of Petrochemicals Ltd. at Carrington, near Manchester. The first stage embraces the production of some 30,000 tons a year of polyethylenes and polypropylenes.

Lang Pneumatic Ltd. have moved to new premises, containing both offices and works, at Owen Road, Wolverhampton.

A private company has been formed by F. Perkins Ltd. to market the organisation's new petrol outboard motors. It is named **Perkins Outboard Marine Ltd.**

Mr. James Hodge, formerly chief engineer of Power Jets (Research & Development) Ltd., has joined Holman Bros. Ltd. in the newly-created post of chief engineer of the group.

A new factory and laboratory have been established by **Morgan Crucible Co. Ltd.** at Wandsworth Works, Point Pleasant, London, S.W.18, for the production and development of sintered metal products.

A third manufacturing plant for the production of pre-coated resin sand for shell moulding and shell core production is now in operation by **Mellor Mineral Mills** (a member of the Dohm Group) at Burslem. The new premises will permit large batch production of the material.

Lawrence & Erausquin (U.K.) Ltd. recently gave a demonstration of the Rand Spray-up process, whereby reinforcement and activated resin are deposited simultaneously, resulting in considerable saving in labour and materials. The company has abandoned the original royalty scheme associated with this equipment, and it is now available for sale outright.

Longer-term grants for special researches will be awarded by the **Department of Scientific and Industrial Research** in future. Normally limited to five years, these grants may now be awarded for an initial period of up to seven years, with the possibility of continuing support for a further ten years.

Star Aluminium Co. have announced the opening of a new laboratory at Wolverhampton to experiment, develop and promote new uses for aluminium foil for the domestic and industrial markets.

Cromoton Parkinson Ltd. have produced three 16-mm. films dealing with their rotating plant, cable and switchgear products. Described as "not too technical, but accurate in technology", they are available to schools, technical colleges and engineering societies.

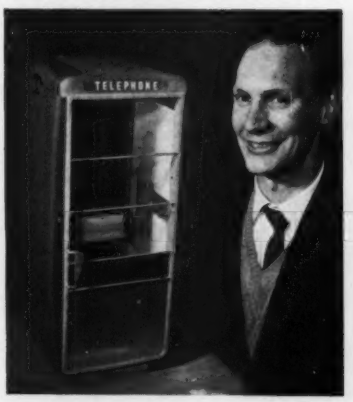
New works have been opened by **Cockburns (Springs) Ltd.** in Glasgow.

Five small furnaces of different design were operated at temperature during a recent exhibition in Birmingham staged by the **Morgan Crucible Co.** to illustrate the versatility of the new Crusilite heating elements. It is claimed that these non-metallic elements (made of one-piece silicon carbide tube using a spiral as the hot zone) have the advantages of simplicity of furnace design, cleanliness and absence of flue gases, and can be used in all temperature ranges up to 1,575 deg. C.

Two British steel firms which have recently acquired new and larger premises are **Sandvik Swedish Steels Ltd.** and **Padley & Venables Ltd.** Sandvik, who are now in new works at Halesowen, near Birmingham, are offering an increased service in the production of special tungsten carbide tools to customers' designs at very short notice. This includes both ordinary and special profiled cutting tools. This company is, of course, backed by the resources of the Swedish parent company.

Padley & Venables have recently taken over a modern factory on the Redhouse Industrial Estate near Walsall. The company has revealed that new stretching equipment is expected to be installed there in the near future, to enable an even higher degree of flatness, in stainless-steel sheet to be obtained, and with less labour, than previously.

Royal Worcester Ltd. have formed a subsidiary known as Royal Worcester Industrial Ceramics Ltd. to cater for ceramics applications in industry.



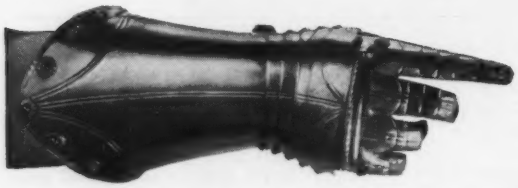
The Horners Award for 1958 (for an article to be made wholly or mainly in plastics) has been won by Mr. R. E. Facius, who is now with British Xylonite Co.

Resin glass-fibre mouldings for the two outer shells and a moulding in translucent glass-fibre for the top are features of his winning telephone kiosk design. Foamed plastics insulation is used in the cavity walls.

New steel and wire annealing furnaces have been installed by **Kayser, Ellison & Co. Ltd.** at Sheffield. Six vertical pit-type furnaces have been built in the wire department for annealing and normalising over a temperature range of 600-850 deg. C. of drawn wire and wire rods. Each furnace will take a charge of 2 ft. 7 in. dia. coils stacked 6 ft. high.

New programming methods have been devised by **E.M.I. Electronics Ltd.** to enable first-class dies to be produced on milling machines, direct from the drawing without the use of an external computer. It is said that forging, casting and plastics moulding dies can all be produced on machines equipped with the new system.

Designer's Diary
is on page 210 this month



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